Energy
Transitions
Commission

State of the transition

Commissioners meeting

27th June 2024

Summary on the state of the transition

Emission trends: Running out of time to limit global warming to 1.5˚C , or even 2˚C

- Energy system emissions rose between 2022 and 2023
- Carbon budget revised downwards in latest estimates

Policies: Measures of last few years in EU, US, China are having an effect – but progress still too slow

- With a number of elections occurring during 2024, there is some uncertainty around potential backsliding on climate policy
- Little progress on NDCs since COP26, in aggregate still lead to 2˚C+ warming, and no sign of strengthening at COP28

The future clean energy system: Progress is uneven – exponential when fast, barely linear when slow

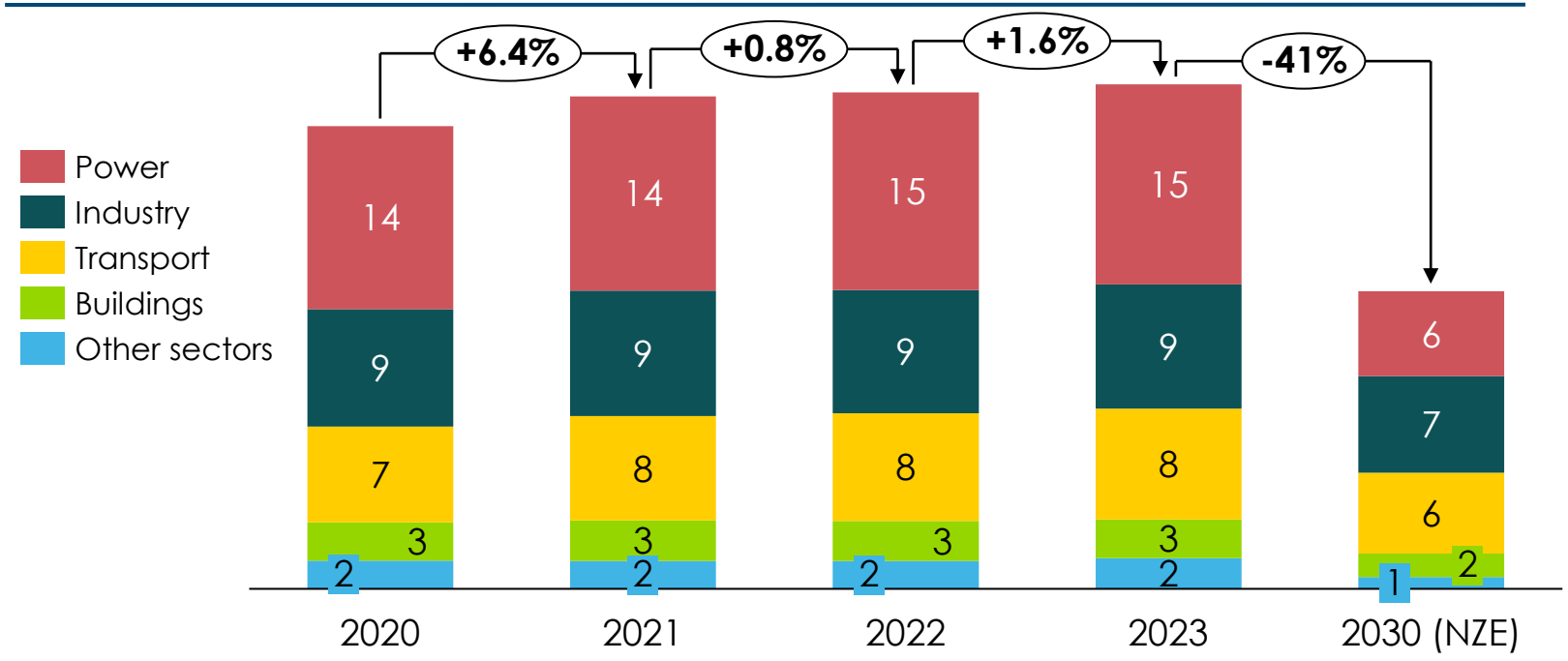
- Some technologies progressing faster than anticipated and reaching clear "tipping points" – e.g. solar and batteries
- Some technologies have faced a slow down in the last year, driven by cost increases, e.g. offshore wind and EVs, but this is expected to be short-lived
- Others require strengthened and focused policy support to drive acceleration: CCUS and heavy industry

Part 1: The state of emissions & key public debates

Emissions from the energy system rose to record high in 2023 and gap with 1.5C pathways continues to grow

Global CO_2 emissions from energy and land use change, 2020-2030

$GtCO_2$/year



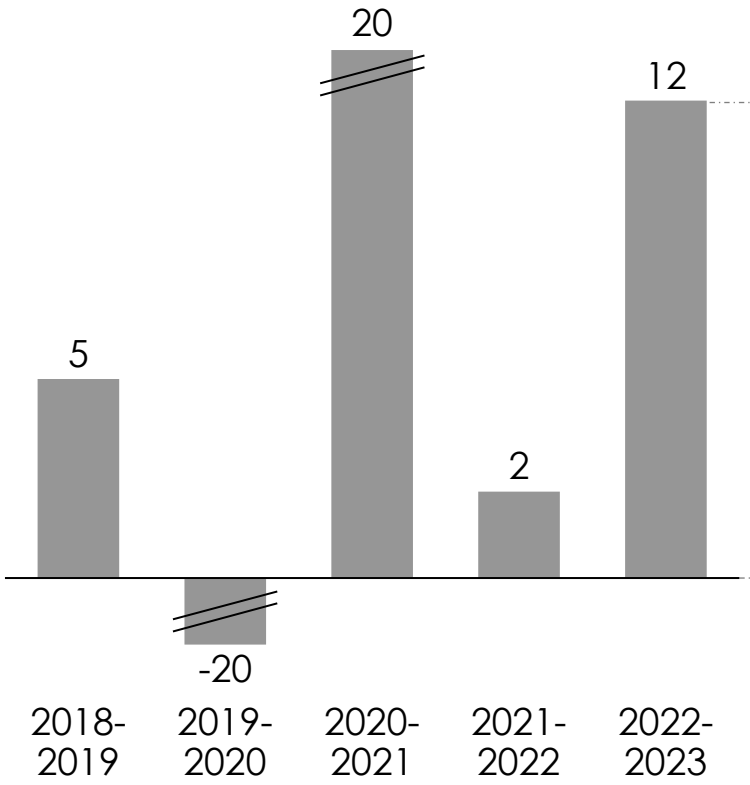
	2020	2021	2022	2023	2030 (NZE)
Total	**38.4 Gt**	**40.4 Gt**	**40.7 Gt**	**41.4 Gt**	
Energy	34.3 Gt	36.5 Gt	36.8 Gt	37.4 Gt	21.2 Gt
Land use	4.1 Gt	3.9 Gt	3.9 Gt	4.0 Gt	

- Despite rising deployment of clean energy technologies, **global emissions have increased** in recent years – clean energy currently limiting growth
- The **gap between actual emissions and the required Net Zero trajectory is growing**, with annual reductions of 7-8% needed each year to 2030 to get on track.
- **Decarbonisation of power** is especially crucial this decade.

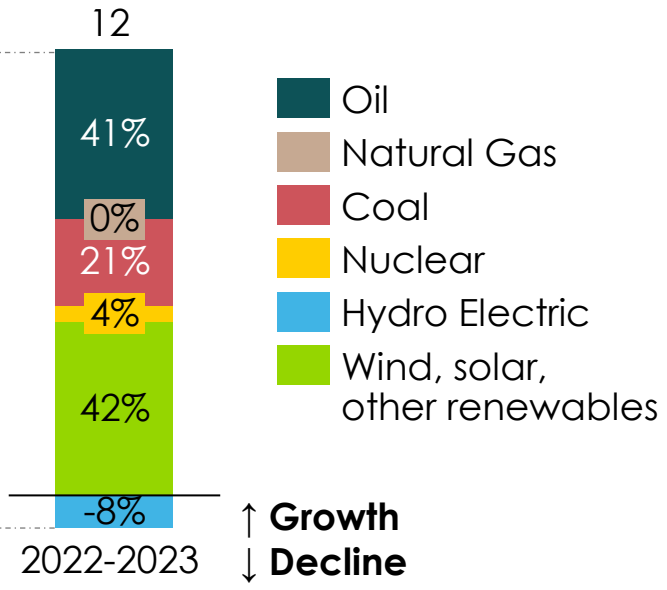
Sources: IEA (2021), *Net Zero by 2050*; IEA (2023), *CO2 emissions in 2022;* Friedlingstein et al. (2022), *Global Carbon Budget 2022;* Carbon Brief (2023), *Analysis: China's CO2 emissions in Q2 2023 rebound to 2021's record levels*; IEA (2024), *CO2 Emissions in 2023*; Pierre Friedlingstein et al. (2023), *Global Carbon Budget 2023*

Growth in final energy demand in 2023, primarily driven by oil and renewables

Change in energy demand
EJ – Net Change



Change in energy supply
EJ, %



Energy demand growth in 2023 accelerated compared to previous year.

10 EJ of 12 EJ demand growth is from China.

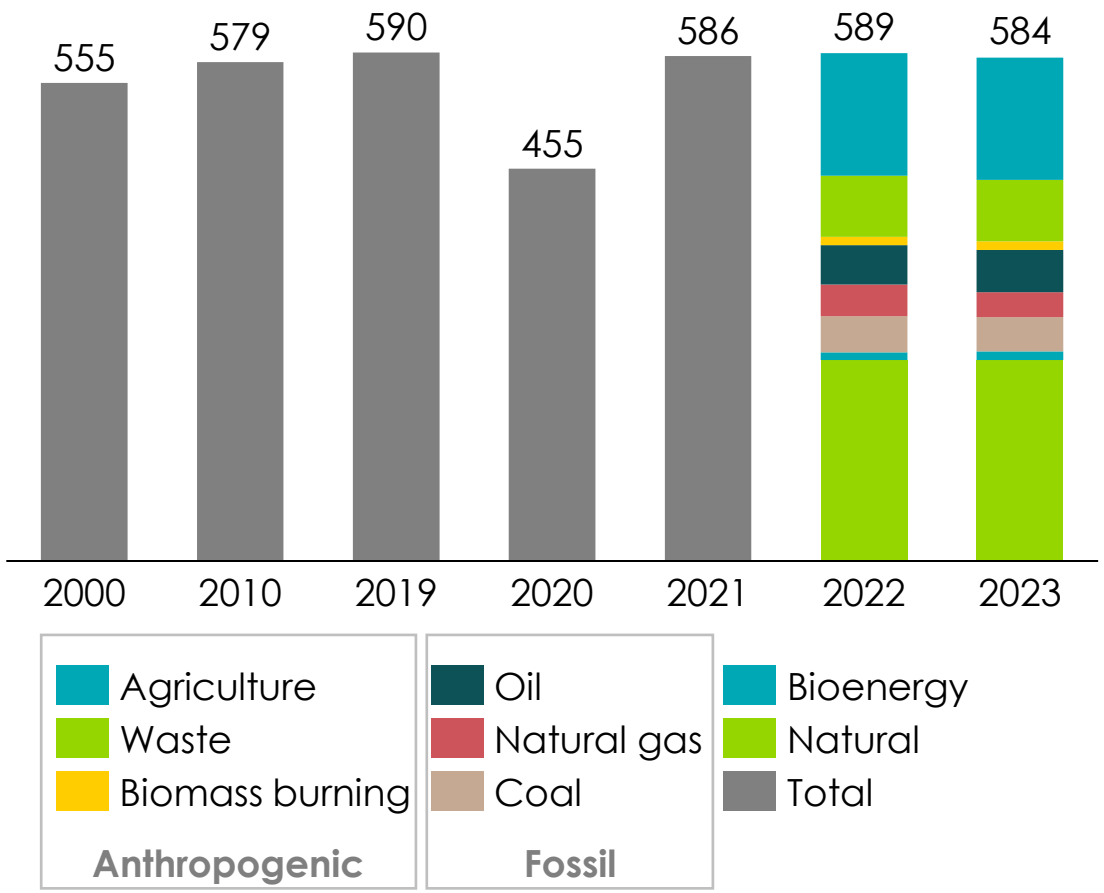
2022-2023 net change primarily driven by increasing oil and other renewables (wind, solar, etc) while hydro in decline.

Source: Energy Institute (2024), *Statistical Review of World Energy*. Our World in Data (2024), *Energy Production and Consumption*. IEA (2024), *Annex A – World Energy Outlook 2023*. Gonzales et al. (2024), *Trends, end-uses, fuels and drivers*. REN21 (2023), *Global Overview*.
Note: share of 2023 energy supply source growth share and 2018-2020 energy demand interpolated from Energy Institute, IEA, and REN21 data.

Global methane emissions appear broadly stable

Note: methane emissions tracking has high uncertainty, particularly for non-fossil sectors. Although atmospheric methane concentrations also dropped in 2023, cannot conclude that small decrease reported here definitively indicates trend.

Global methane emissions
Mt



Global methane emissions have steadily increased, only interrupted during Covid pandemic due to reduced human emissions.

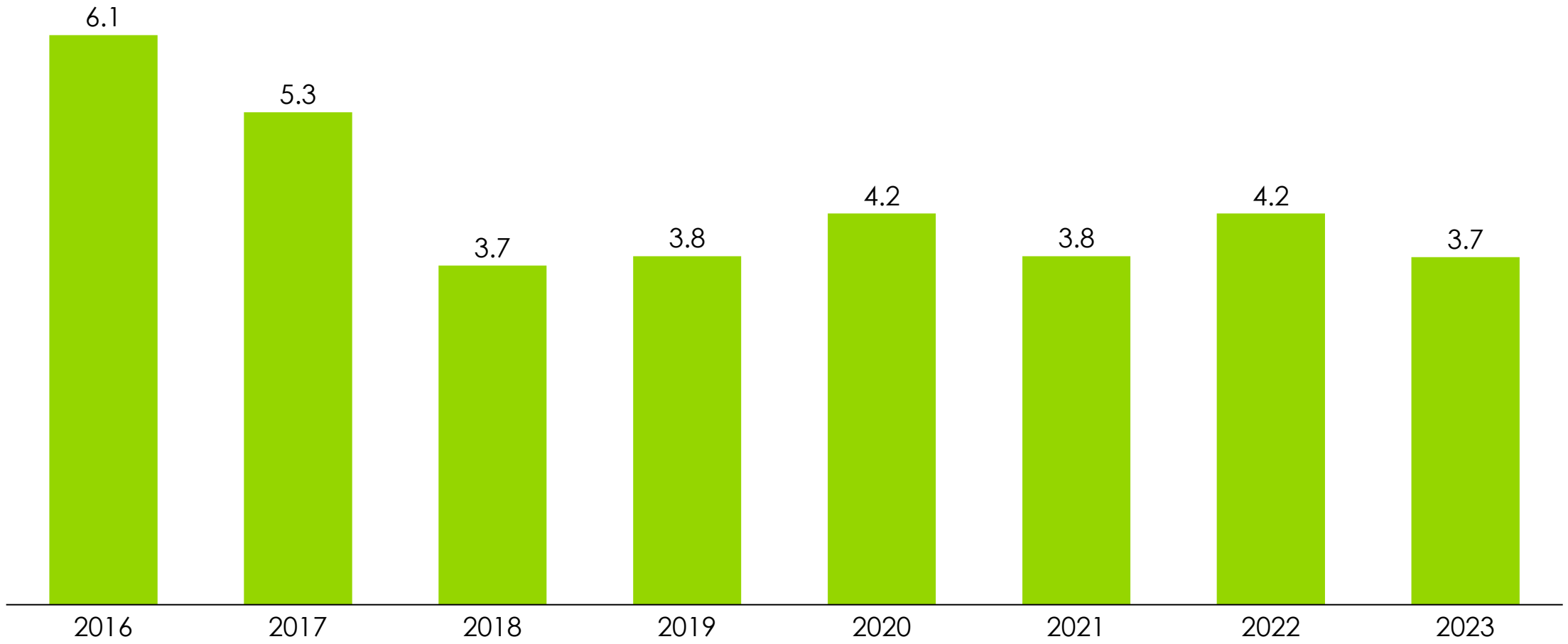
2022-2023 saw small fossil emissions decrease

Reducing the rate of methane emissions increase is particularly important, as its a short-lived greenhouse gas.

Source: IEA (2024), *Global Methane Tracker;* ESSD. Copernicus (2024), *The Global Methane Budget 2000-2017*.
Note: Methane emissions from natural sources are approximately 233 Mt p.a., accounting for currently ~40% of global methane emissions, next to ~60% from human activity;

Global primary forest loss decreased in 2023, and has reduce significantly over from 2016 levels

Global primary forest loss
Million hectares per year

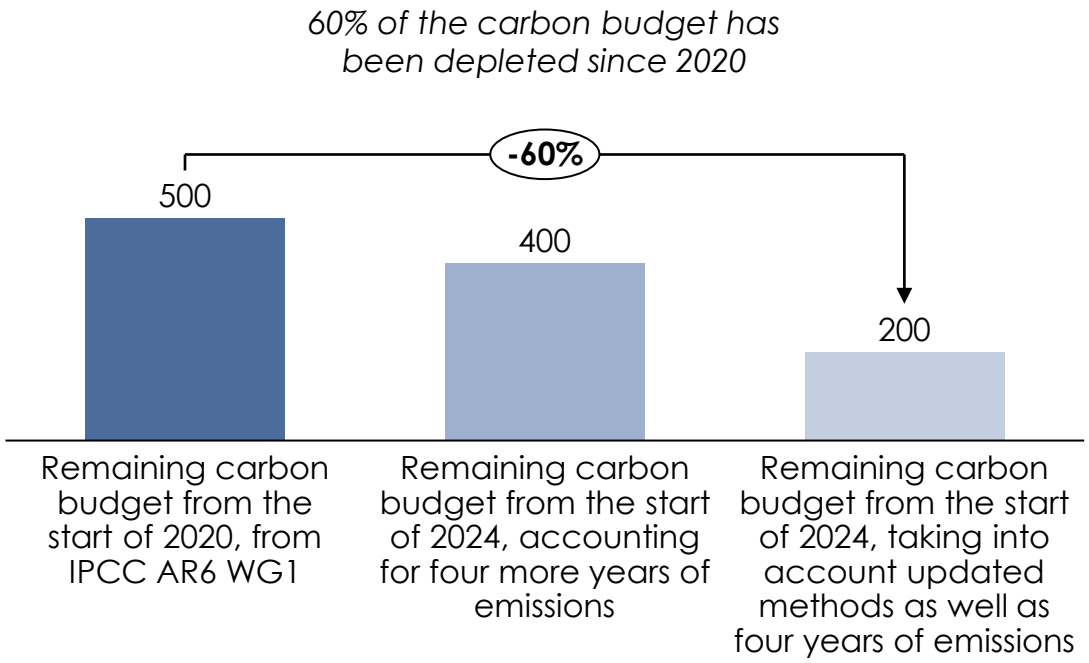


Source: Global Forest Watch (2023)

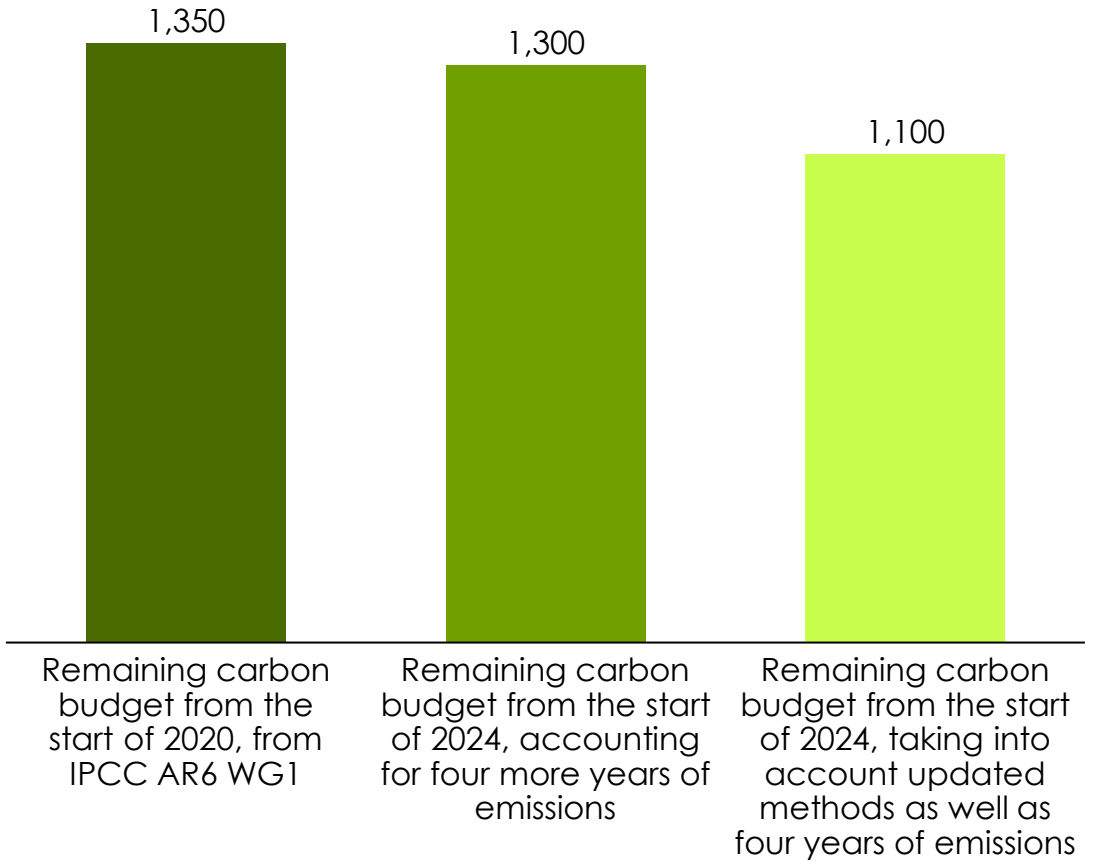
Carbon budgets to limit global average temperature increase to 1.5°C and 2°C have decreased, increasing the urgency of action in the short term

Carbon budgets for a given temperature rise, In $GtCO_2$

Budget for 50% chance of staying within 1.5°C



Budget for 50% chance of staying within 2°C



Source: Forster et. Al (2024) *Indicators of Global Climate Change 2023: annual update of key indicators of the state of the climate system and human influence*

Ambitious action on climate change is facing increasing pushback as policies are introduced

EU climate policies could be slowed in future after rightward shift in election

Election of Donald Trump 'could put world's climate goals at risk'

Lobbyists fight to keep the EU's 2035 gas car phase-out alive

US regulators approve significantly scaled back climate disclosure rule

Ignored at the ballot box: The absence of climate change in Indian politics

Analysis

Sunak backtracked on climate policies – and voters may punish him

As elections are undertaken around the world, unclear that major shifts in climate policy will emerge – US, possibly France as big swing factors

Non-exhaustive

National elections	Impact on climate policy	Details
United States President, Senate, House of Representatives	Unclear	• US climate and energy policies have seen significant developments, including the passage of the IRA • Renewable sources surpassing coal and nuclear power in electricity generation in 2022 – signal **a shift toward decarbonisation** • The **pace and depth of decarbonization** depend on the 2024 presidential election outcomes
European Union European Parliament	Unclear	• Centrist parties continue to hold a majority in the new European parliament • The **stronger presence of right-wing parties** could make ambitious new climate policies **harder to pass**
India General election	Likely peripheral	• The Modi-led government has been seen as a **climate leader comparing to other parties** • It also faces **criticism for its coal expansion and ties to fossil fuels** • Climate issues are **historically peripheral**, but they are **becoming more central** in political discourse
France National Assembly	Likely negative	• Green parties suffered losses in France • **Far-right parties** have made big gains
Mexico President, Senate, Chamber of Deputies	Unclear	• The new president Sheinbaum has a climate scientist background • Support **solar energy** and **electrified public transport** • Faced criticism for **limited environmental improvements** when she was Mexico City mayor

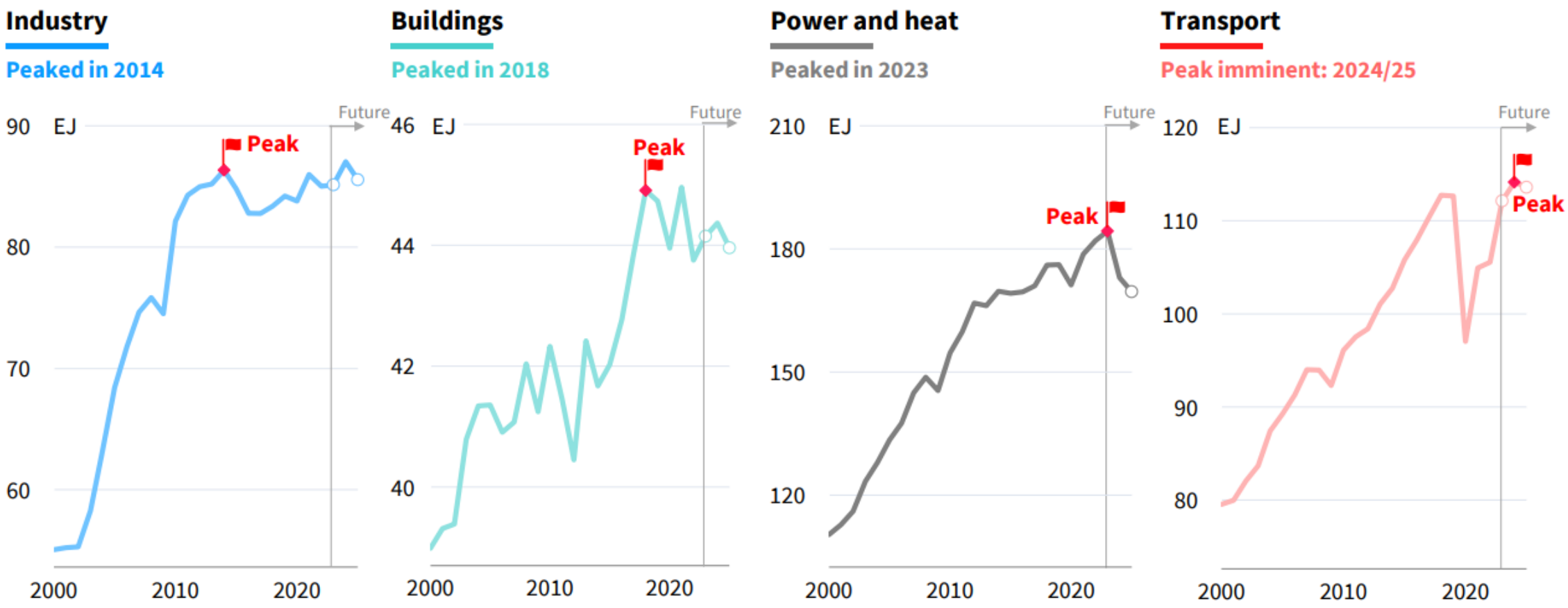
United Kingdom
House of Commons
	Likely positive	• Both parties aim to **maintain UK's 2050 net-zero target**
		• Conservatives emphasize an "**affordable and pragmatic**" transition
		  • Focus on avoiding additional costs for households
		• Labour party aim to "**restore strong global leadership**"
		  • Propose a new "**Clean Power Alliance**" to unite countries leading in climate action

Indonesia President, Parliament	Likely peripheral	• Prabowo likely to continue Jokowi's climate policies • Faces **challenges balancing coal dependency** with sustainable energy

Source: Climate Action Tracker (2024), *USA*; Euro News (2024), *The UK election and climate change: Where do political parties stand on 6 key issues?*; Carbon Brief (2024), *Experts: What do the European elections mean for EU climate action?*; Carbon Brief (2024), *India election 2024: What the manifestos say on energy and climate change*; Climate Scorecard (2024), *Indonesia's President-Elect Has a Good Climate Policy, but Will He Implement It?*; The Guardian (2024), *Mexico's new president ran on climate goals. Will she follow through?*

Peak fossil fuel demand for Industry and Buildings has already occurred; Power and heat, and Transport is happening now

Fossil Fuel demand by sector, EJ



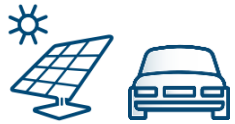
Source: RMI (2024) *The Clean Tech Revolution*, based BNEF 2024 NEO.

Part 2: Progress towards the net zero energy system

The technologies which are deploying fastest are those most susceptible to mass production and easy deployment

Fastest progress

Slower progress

Solar PV, EVs and batteries		▪ Mass produced in large-scale, replicable factories ▪ Easily transported ▪ Easily deployed / installed
Heat pumps		▪ Mass produced in large factories ▪ Easily transported ▪ Complex installation
Wind		▪ Turbines supply chains very complex, scale of production is orders of magnitude smaller than PV/batteries ▪ Higher degree of customisation for projects ▪ Transport and installation more complex
Electrolyser and green H_2		▪ Can be mass produced, but balance of system costs and specific project complexities important
CCUS		▪ Customised engineering design and deployment
Large-scale nuclear		▪ Hugely complex large-scale systems

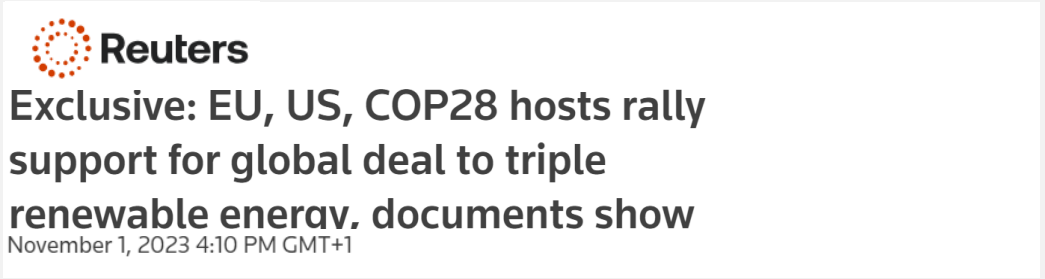
Key issue: opportunity for standardised and/or smaller scale units?

- *Standardised CCUS units?*
- *Small modular nuclear?*

Power

Trebling renewables – likely possible: address wind challenges; invest more in low- and middle-income countries

118 countries pledged to triple renewable energy capacity


Reuters

Exclusive: EU, US, COP28 hosts rally support for global deal to triple renewable energy, documents show

November 1, 2023 4:10 PM GMT+1


EURACTIV

Global coalition pledges to triple renewables, double energy efficiency improvements

Dec 2, 2023

How to get there?

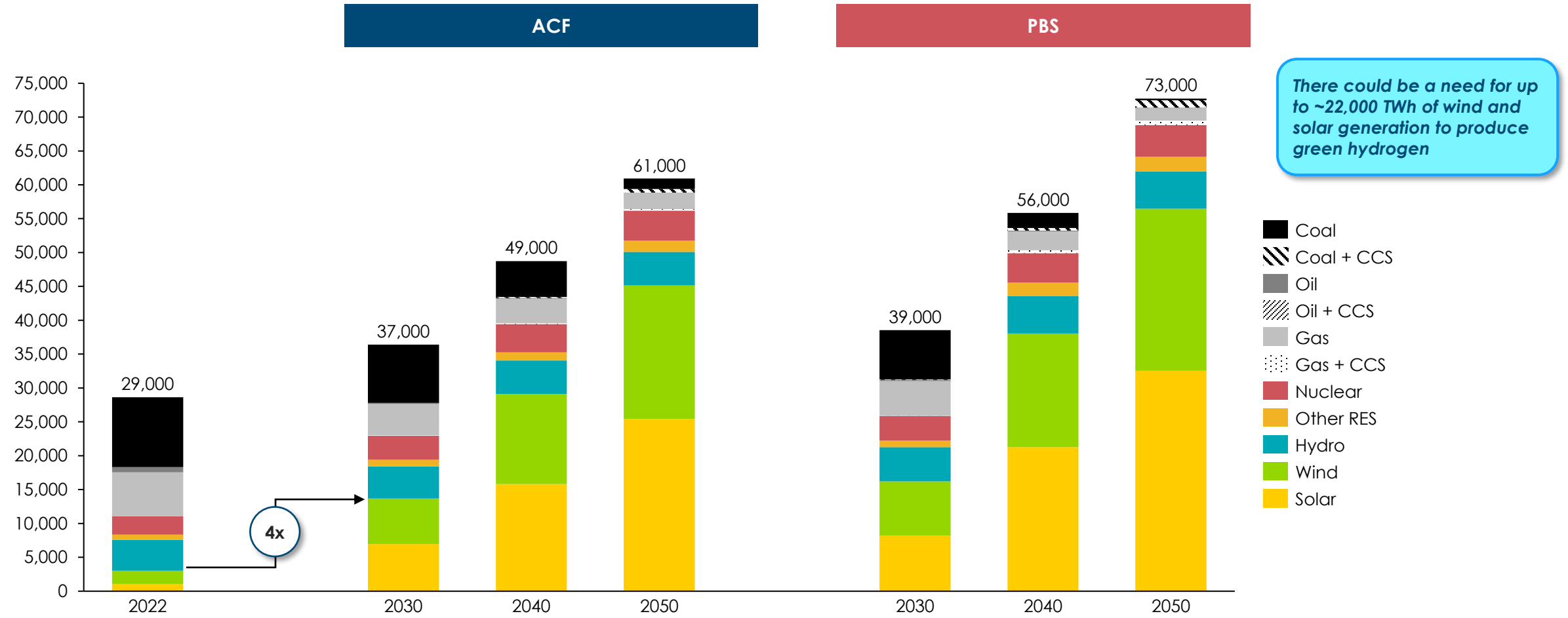
- **Strategic vision:** constantly raising ambition for clean power system
- **Faster permitting** – halving timescales for wind, solar
- Parallel **build-out of power grids**
- Fixing **wind supply chain challenges**
- Quadrupling of investment in **low- and middle-income countries**, to **~$650 bn p.a. by 2030**

Note: [1] The COP28 agreement included a global target to treble renewables (incl. solar, wind, hydropower, bioenergy, geothermal) by 2030. This would involve a roughly 5x increase in solar PV and 3x increase in wind from 2022.

Source: Systemiq analysis for the ETC; BNEF (2023), *Interactive Data Tool – Global Installed Capacity*; ETC (2021), *Making clean electrification possible*. Euractiv (2023), *Global coalition pledges to triple renewables, double energy efficiency improvements;*

Global power generation will have to increase by 2-2.5* by 2050, with potential large additions for green hydrogen

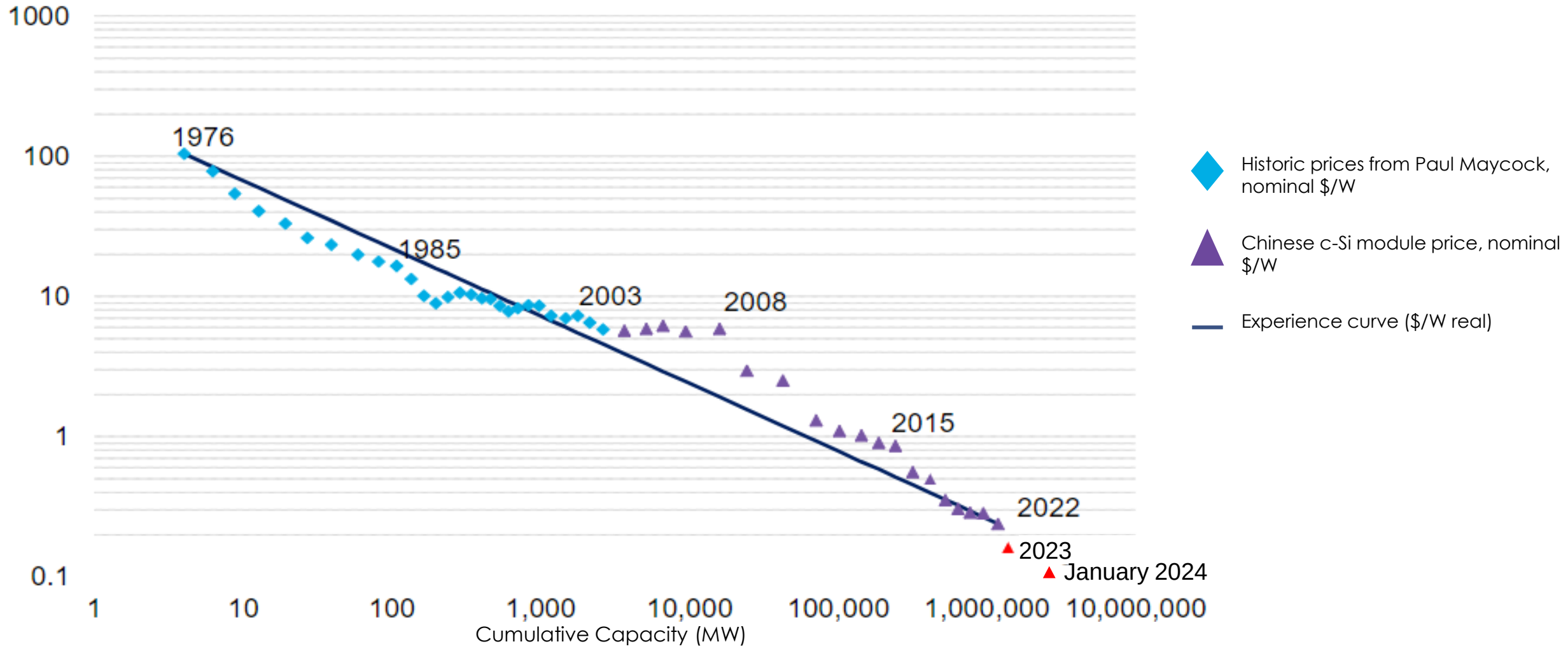
Global power generation by source



Note: Figures include power demand from DACCS from 2030 onwards. There could be a need for up to around 22,500 TWh of wind and solar generation to produce green hydrogen as it may be underestimated in the regional power generation analyses we have aggregated, relative to ETC's analysis of potential demand for low-carbon hydrogen
Source: Systemiq analysis for the ETC (2023).

The crystalline silicon PV experience curve shows the significant reduction in solar over the past 50 years

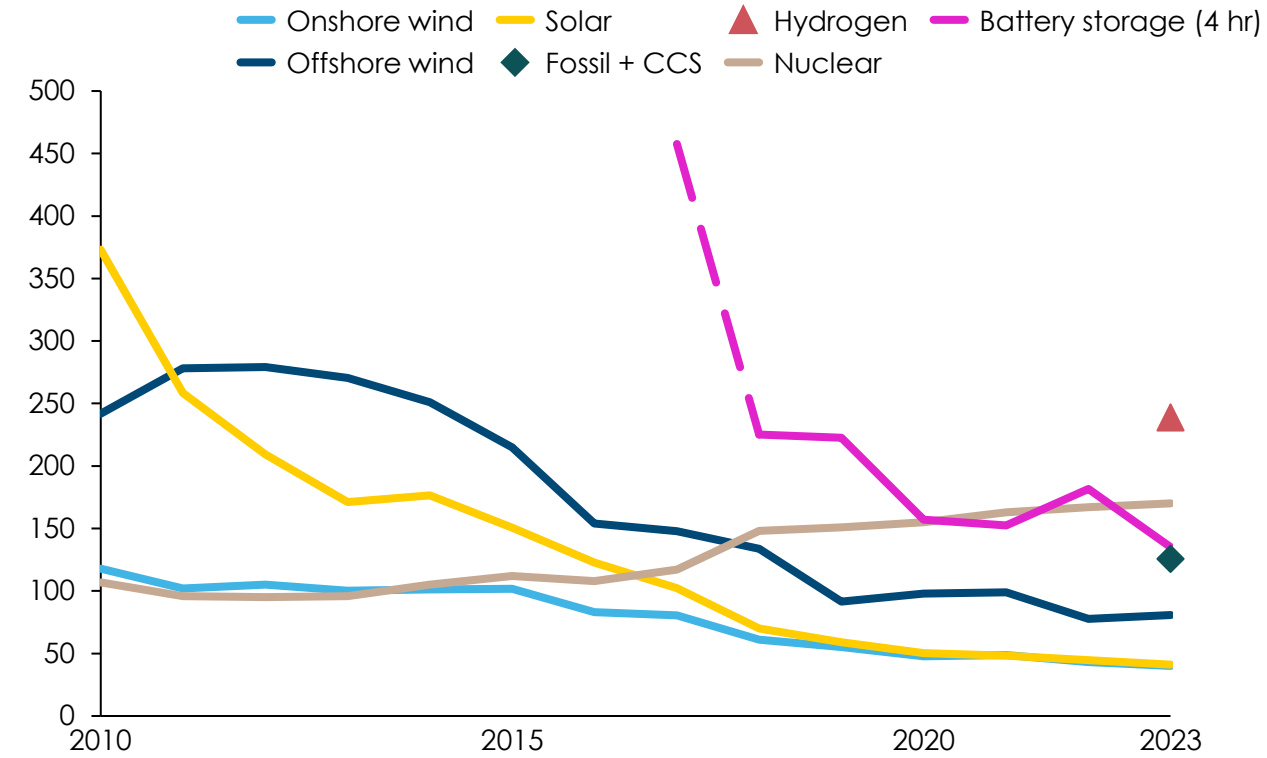
$/W (real 2023)



Wind and solar continue to be competitive against fossil fuels, but cost declines have slowed in past few years

Global LCOE benchmarks for renewables remain competitive

$/MWh (real 2022)



- Onshore wind and solar **remain the cheapest new build technologies.**
- Whilst **offshore wind** costs have increased outside of China, these **should be short-lived.**
- **Cost declines have slowed**, with higher financing costs offset by falling input prices.
- **Four-hour battery storage fallen to record lows** of $135/MWh, due to large increases in supply and demand.
- Recently, renewable costs have **fallen inside of China and increased elsewhere**.

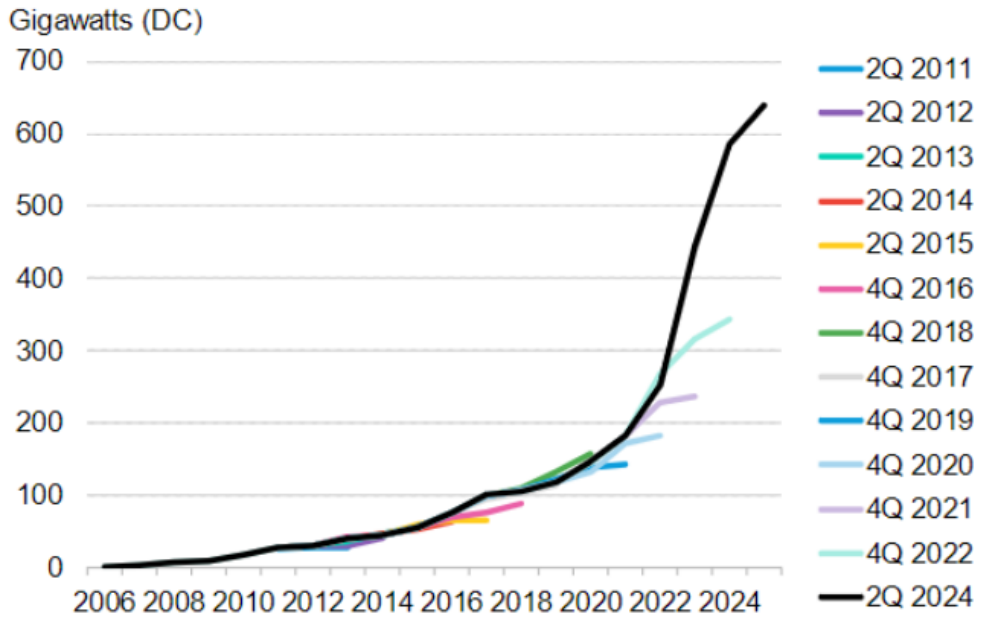
Notes: The global benchmarks are capacity-weighted averages using the latest country estimates – apart from nuclear, hydrogen and CCS, which are simple averages. Offshore wind includes offshore transmission costs. Fossil + CCS is the average of Coal- and gas-fired power include carbon pricing where policies are already active. LCOEs do not include subsidies or tax-credits. Solar refers to fixed-axis PV. Nuclear data from Lazard

Source: BNEF (2023) *2H 2023 LCOE Update*; Lazard (2021), *LCOE, Levelized Cost of Energy Comparison—Historical Utility-Scale Generation Comparison*

Whilst newest Net Zero scenarios assumes slowdown in solar over the long term, it may continue at a high level

BNEF forecasts of Solar new build vs realised deployment

GW

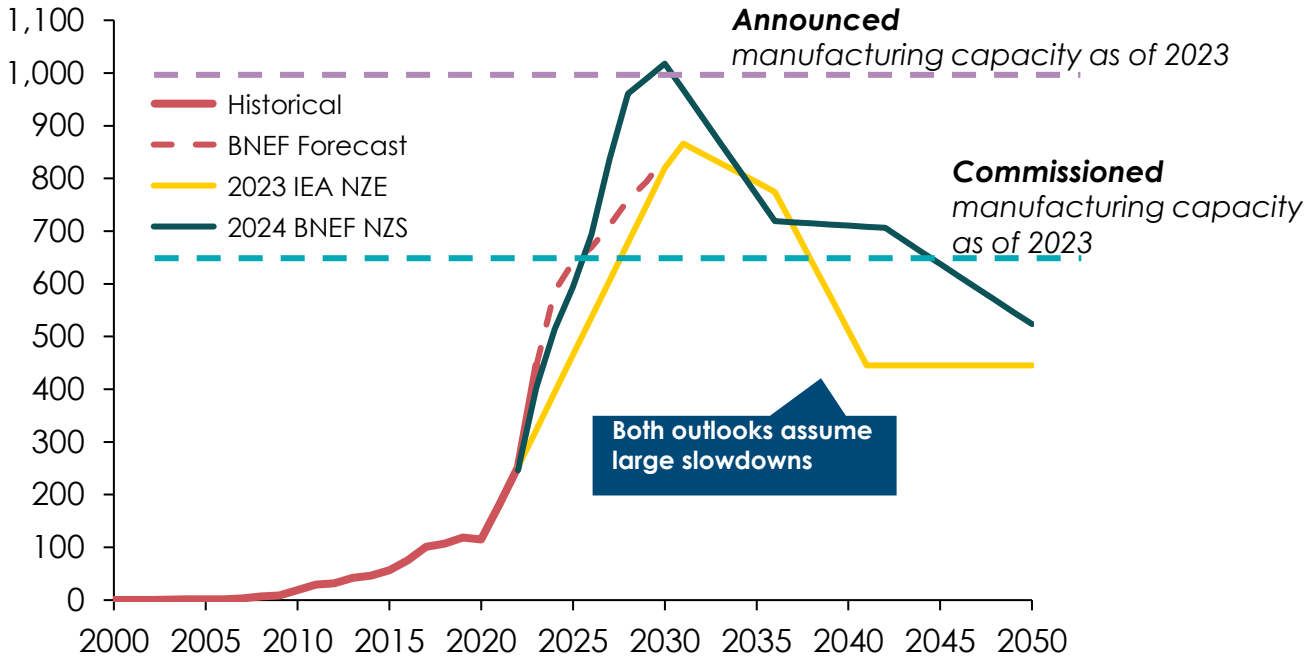


Source: BloombergNEF Note: Chart shows forecasts over 2011-2022, and current forecast to 2025.

Forecasters consistently underestimate the potential of solar additions, and we don't know how high these could reach

Annual solar PV installations compared to forecasts

GW



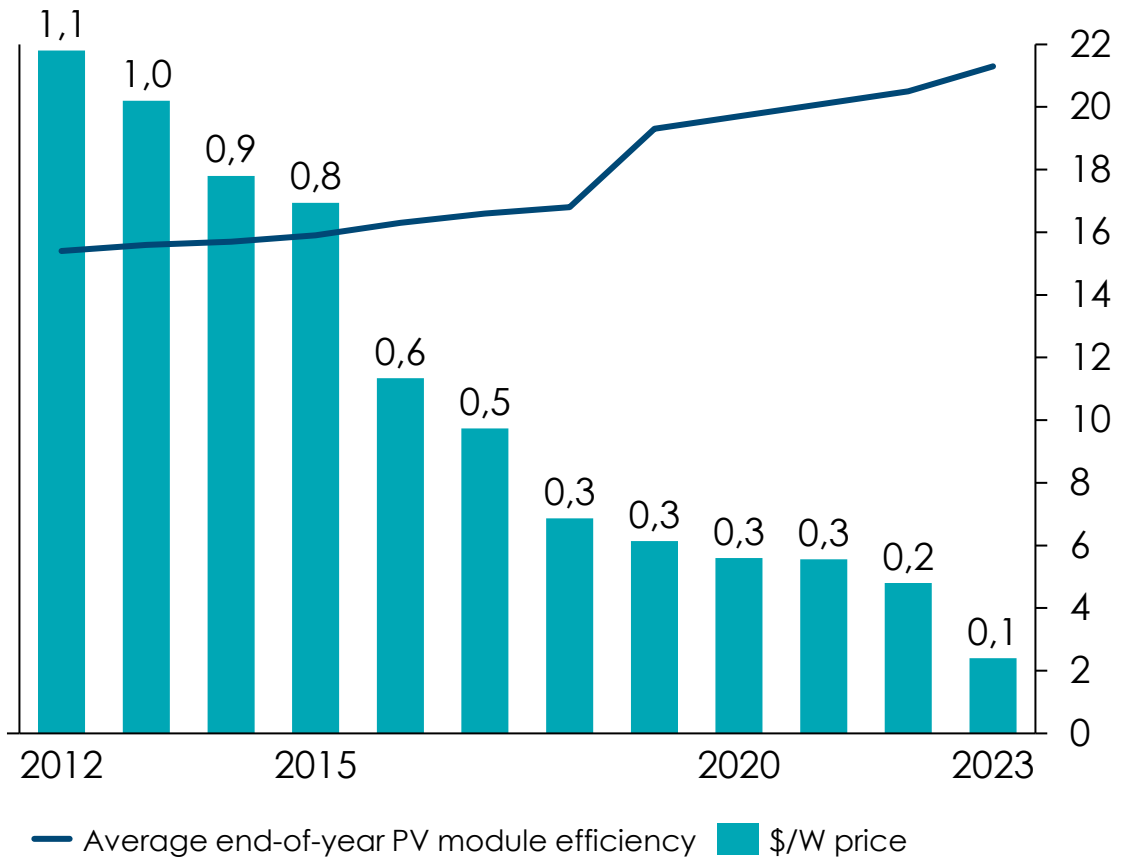
Whilst the newest IEA/BNEF Net Zero scenarios anticipate strong acceleration of solar through to 2030, deployments then start to tail off

Source: BNEF (2024), *Global installed capacity*; BNEF (2024), *2Q 2024 Global PV Market Outlook*; IEA (2023), *Net zero roadmap – update;*

As solar prices plummet, PV innovations surge

Solar module price[1] – against module efficiency development

$/W / %



Increased focus required on other aspects of 'Balance of plant' like inverters, mounting, and wiring.

Solar inverter & other BoP = around $5-10/MWh of LCOE[2]

Improvements start to outweigh costs and efficiency penalties of light weight panels.

Light weight (-60%) and flexible solar panel

Building Integrated PV becoming more cost-competitive

Solar tiles

Solar windows

Source: Nat Bullard (2024), *Annual Presentation.*

Note: [1]Solar model price refers to median price development across different panel technologies. [2]Based on utiility scale solar at $30/MWh.

Agri-solar photovoltaics as innovation step for PV deployment, can unlock synergy effects to drive significant PV deployment

Suitable crops
Can thrive under partial shade of PVs

Shade tolerant (e.g. lettuce, spinach, root vegetables such as carrots, certain herbs)	**High Value crops** types of fruits and vegetables can benefit from shading.
Cool-season crops, e.g. broccoli, cauliflower, kale.	**Robust perennial plants**, incl. grasses and forbs used for grazing livestock.

Usable share of total arable land varies (Norway ≈1%, Denmark ≈50%)

Synergy effects

For agriculture	For solar PV
Higher land productivity ~35-73% more efficient than for either agriculture/solar use alone.	
Diversified income streams	
Shared infrastructure costs	
Lower operating cost e.g. saving water via better on-site water distribution, in arid/very wet areas.	**Reduced panel wear and tear**, from reduced ground temperature **Increased social acceptance and access to large subsidies** for agriculture

Economic potential

Improved yields for agriculture + Positive externality – e.g. better biodiversity* + Improved yields from higher PV deployment

CAGR 12% ↗ Global agrivoltaics market expected to grow from $4.6bn in 2022 to $11bn in 2030

Big potential contribution to energy transition

51 TW in EU

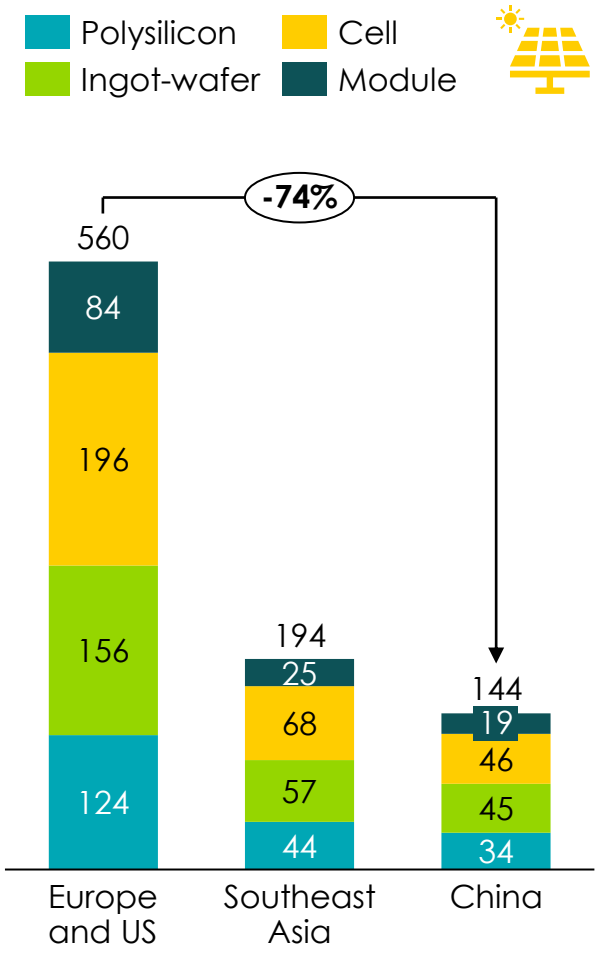
Fraunhofer study: "***Potential enormous**…could produce **25-times the current electricity demand** in Europe"*

Sources: Fraunhofer (2024), *Agrivoltaics Opportunities for Agriculture and the Energy Transition;* Aminata et al. (2023), *Agrivoltaic, a Synergistic Co-Location of Agricultural and Energy Production in Perpetual Mutation: A Comprehensive Review*; Green Dealflow (2021), *The new-no limit photovoltaics;* PV Magazine (2023), *New Research identifies potential for 51 TW of agrivoltaics in Europe;* Picture from PV Magazin (2023), *New solar canopy for agrivoltaics from France.*
Note: Positive externality not considered in global agrivoltaics market estimations.

China is more cost competitive than other countries across all major clean energy technologies

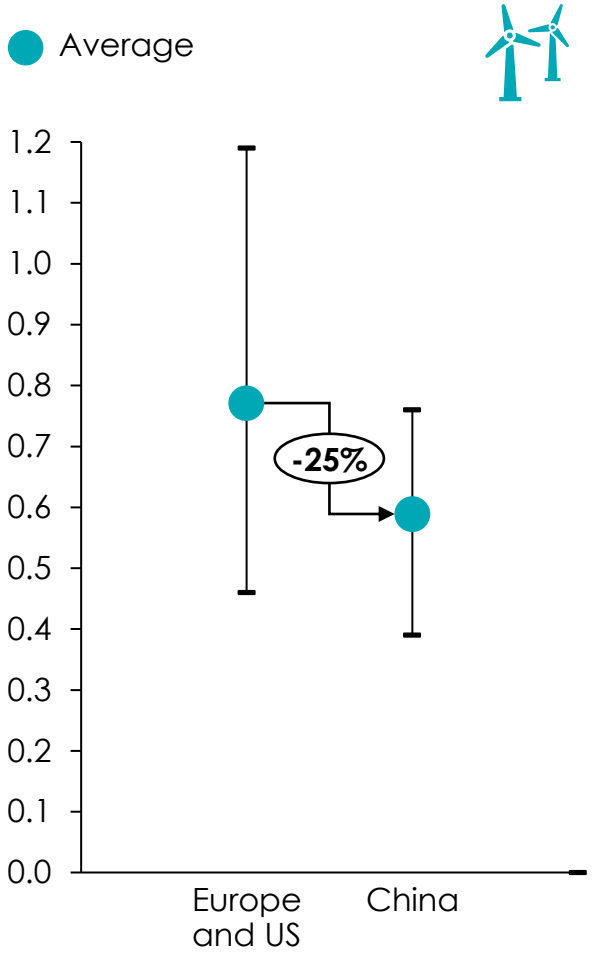
Estimated capex per unit for factories of solar PV components

US$ million/GW/year



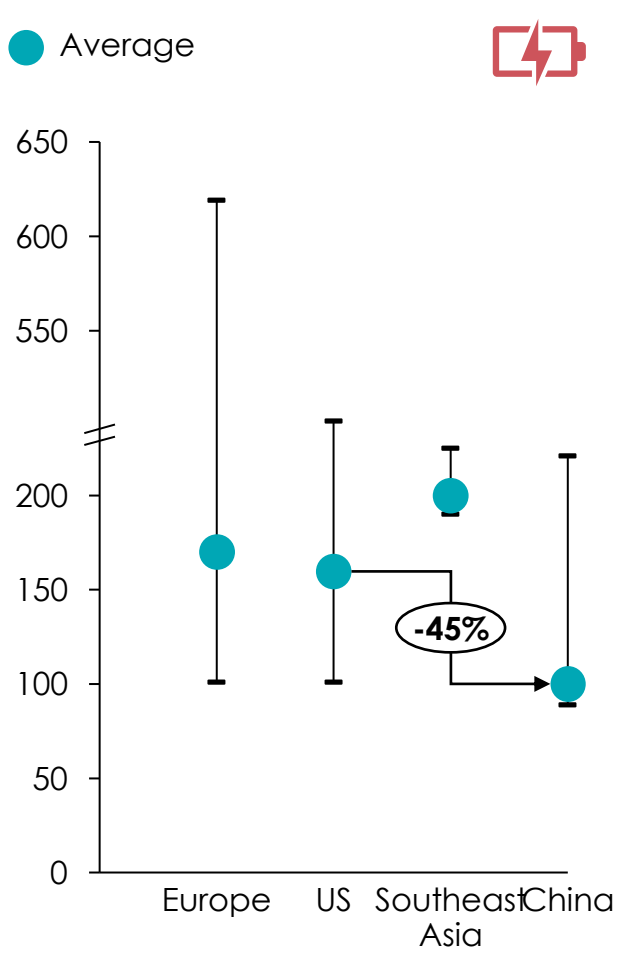
Chinese and Western wind turbine price range outside China

US$ million per MW (nominal)



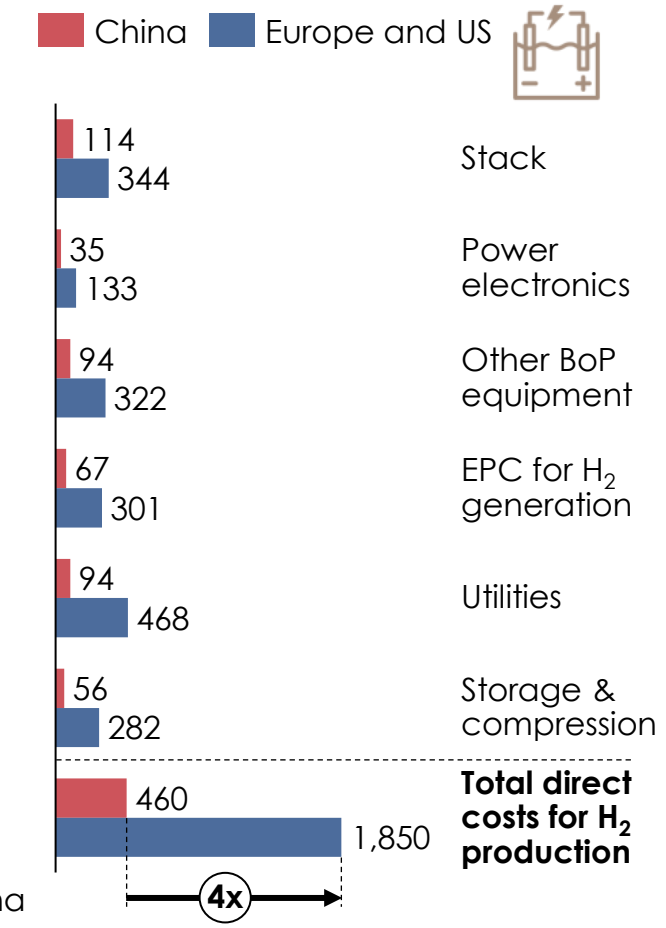
Volume-weighted battery pack price range by region

Real 2022 US$/kWh



Capex components of alkaline electrolysis projects

Real 2023 US$/kW

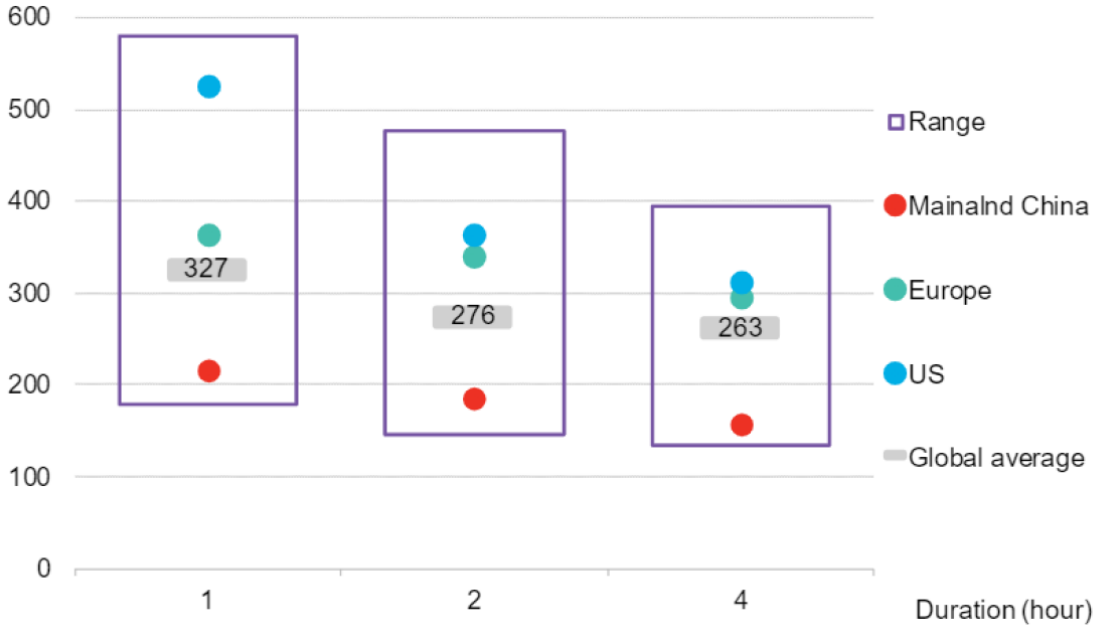


Source: BNEF (2022), *Building Solar Factoring to Rival China Won't Be Cheap*; BNEF (2023), *Europe's Bid to Reshore Clean Tech Pulls Its Punches*; BNEF (2024), *China's Intense Wind Market Sees Cheap Turbines Drive Loss;* BNEF (2024), *Electrolyzer Price Survey 2024: Rising Costs, Glitchy Tech*

In China, lithium-ion battery storage system prices were already the lowest in the world, and have fallen rapidly in the past 12 months

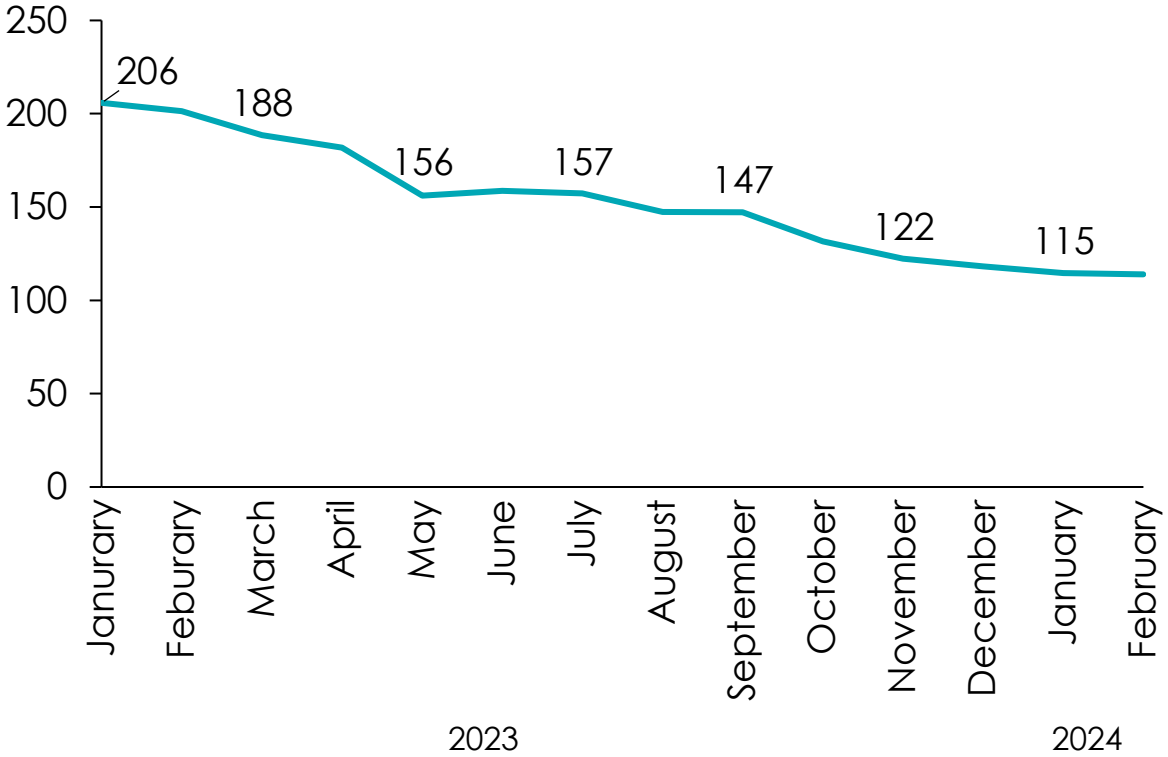
Turnkey LFP storage systems costs and ranges 2023, by region

$/kWh



Two-hour turnkey energy storage costs in China

$/kWh



Chinese turnkey battery storage systems were around 40% cheaper than other countries in 2023…

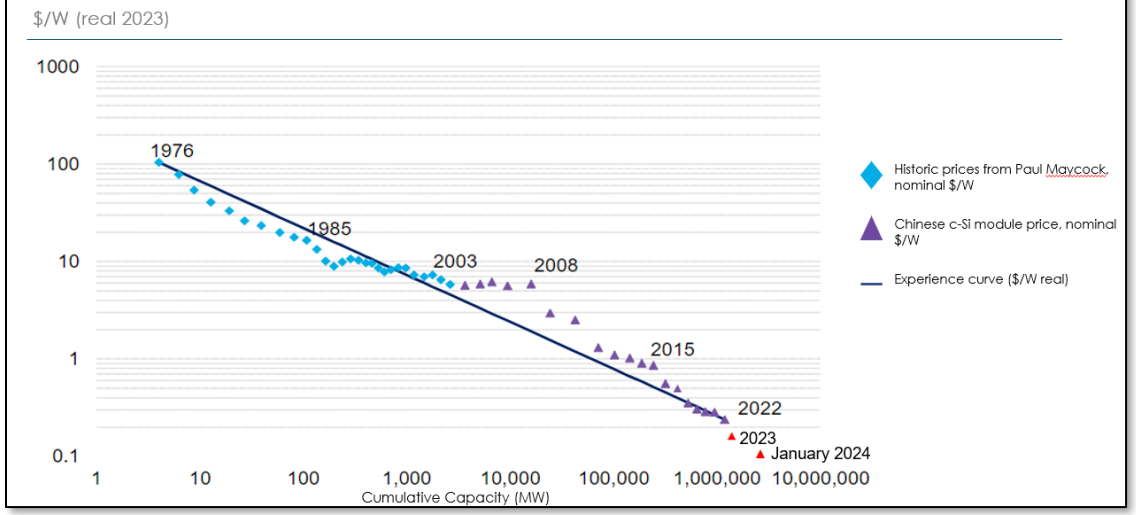
…and prices have fallen another 40% since January 2023

Notes: Average prices used for all project durations. Pricing based on useable capacity. Prices converted using December 2023 exchange rate.
Source: BNEF (2024), *1H 2024 Energy Storage Market Outlook*

Solar and battery price collapsing, opening up a new world of opportunities.

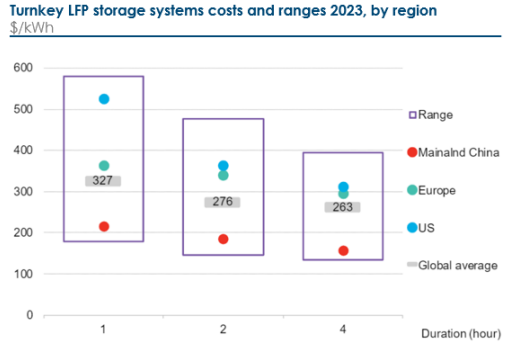
Falling solar costs

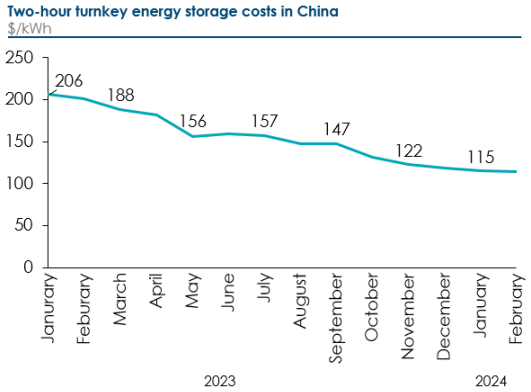
The crystalline silicon PV experience curve shows the significant reduction in solar over the past 50 years



Falling battery costs

In China, lithium-ion battery storage system prices were already the lowest in the world, and have fallen rapidly in the past 12 months





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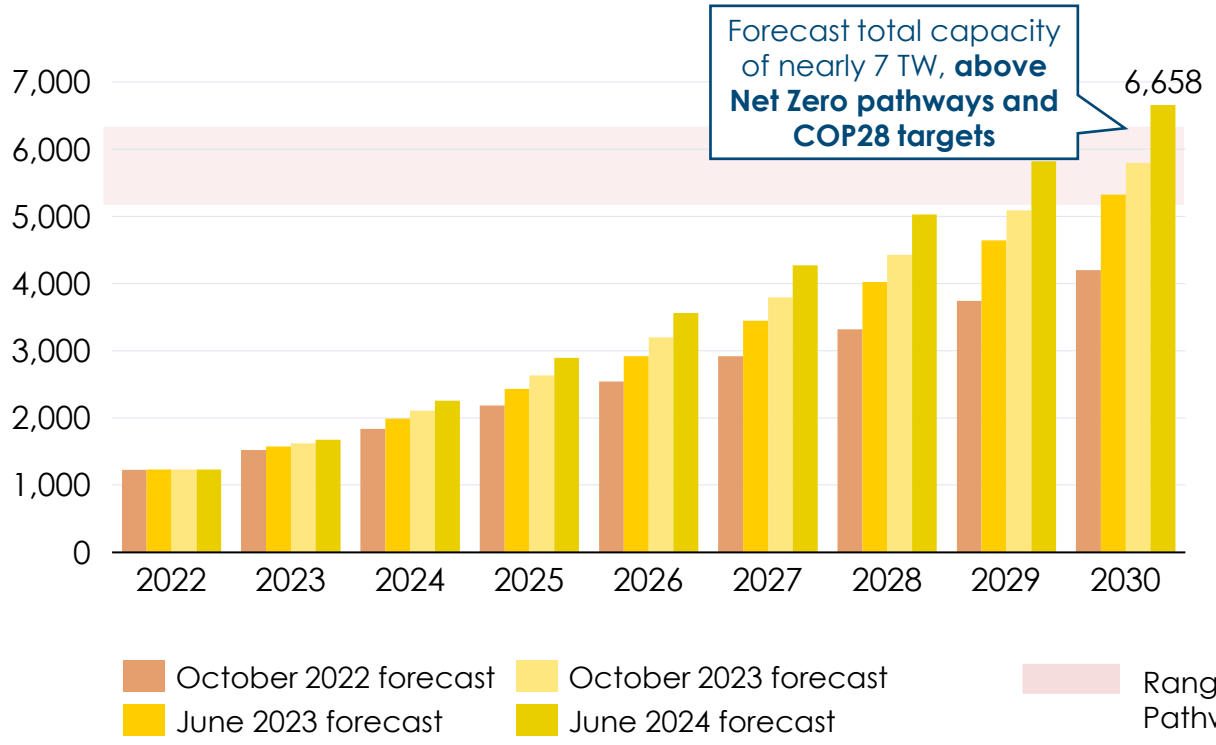
- Solar + batteries replacing diesel generators?
- Solar + batteries for 24h power
- Solar + batteries for new applications & unknown possibilities?

Solar forecasts are powering past pathway for 1.5C, thanks to enhanced manufacturing, while wind energy, hampered by restricted growth outside China, lags

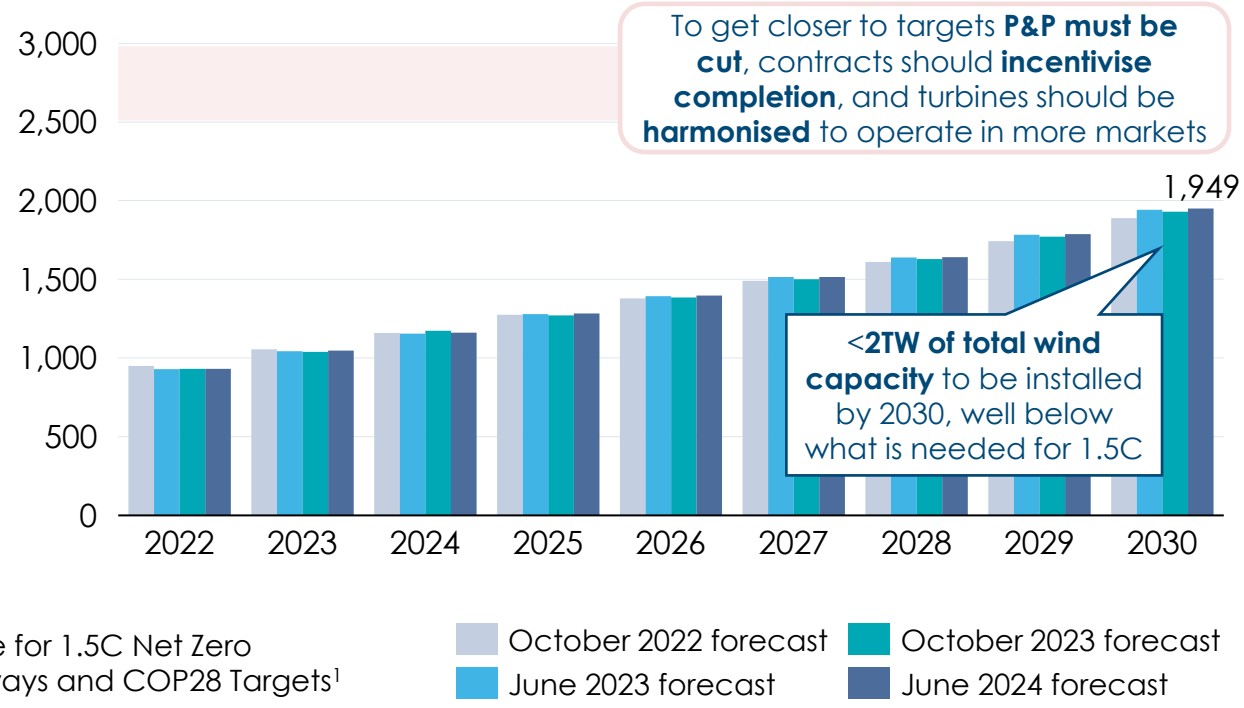
Recent solar forecasts are now aligned to ETC 2030 milestones

GW total capacity installed



Recent wind forecasts still fall behind ETC 2030 milestones

GW total capacity installed



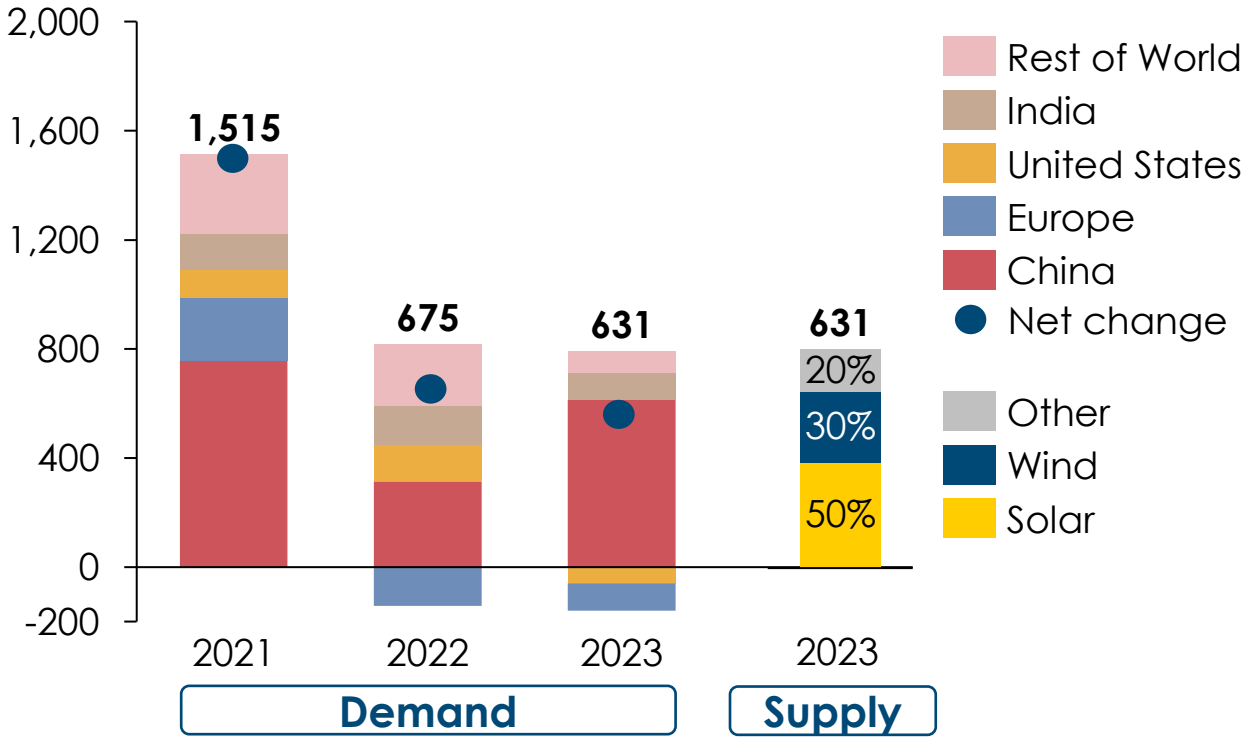
Solar forecasts keep accelerating due to manufacturing capacity buildup and the modularity of panels

Continued slow growth for wind ex-China, where barriers are higher (e.g. supply chain, land allocation, permitting)

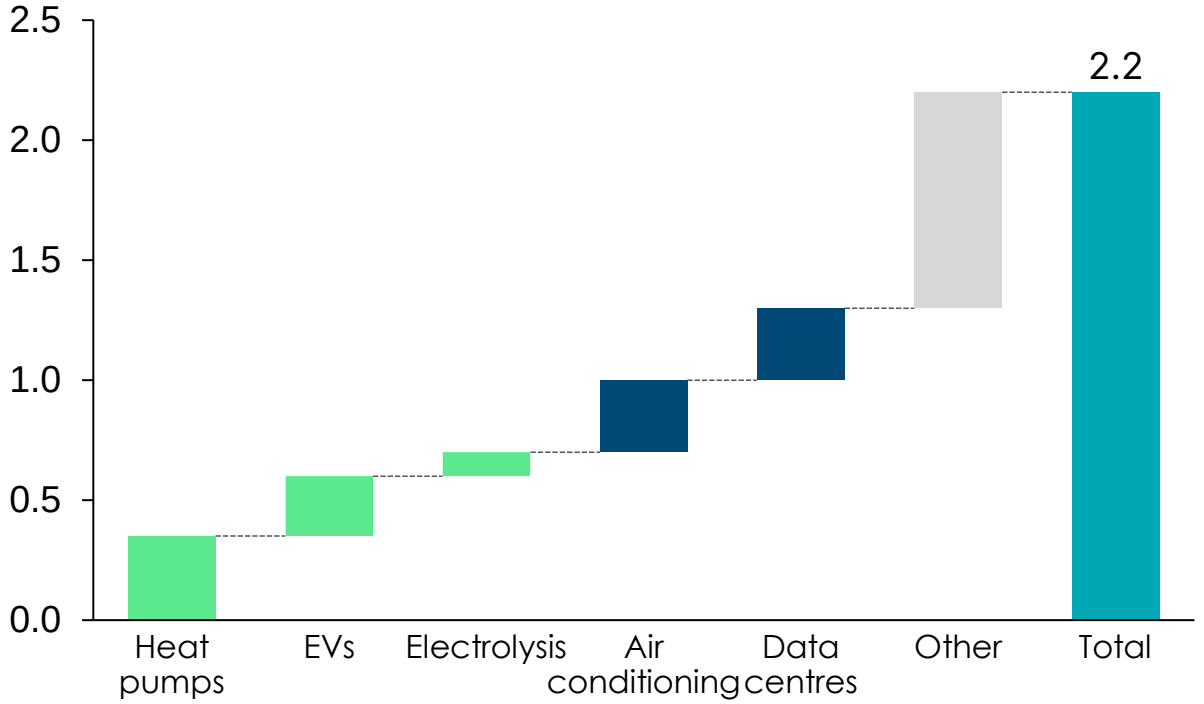
Note: [1] The COP28 presidency has a target to treble renewables (incl. solar, wind, hydropower, bioenergy, geothermal) by 2030. This would involve a roughly 5x increase in solar PV and 3x increase in wind from 2022.
Source: Systemiq analysis for the ETC; BNEF (2022/23/24) *Global Installed Capacity*

Increase in 2023 global electricity demand was driven by China, with 4 key technologies contributing most

Increase in global energy demand and supply
TWh, demand 2021-2023, supply 2023



Share of global electricity demand growth attributed
Percentage points



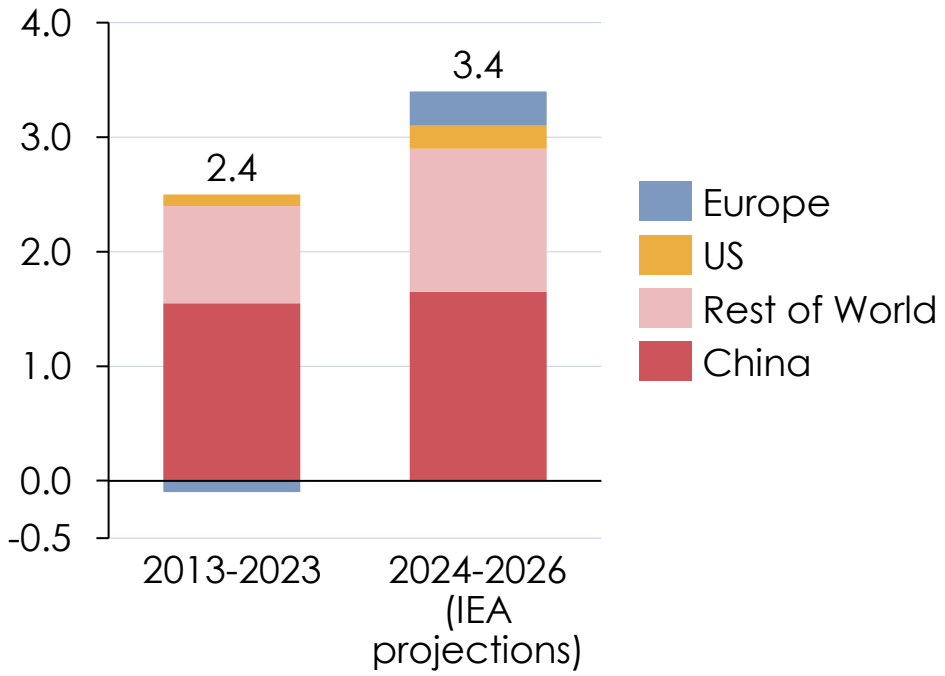
Chinese demand increased 610 TWh (7%) in 2023, whilst European and US demand declined by 100 TWh (2%), and 60 TWh (1%) respectively

Over 60% of electricity demand growth was from EVs, heat pumps, air conditioning and data centres

Notes: Other includes TVs, cooking and other appliances
Source: Ember (2024), *Global Electricity market Review 2024;* Ember (2024), *Electricity data viewer*

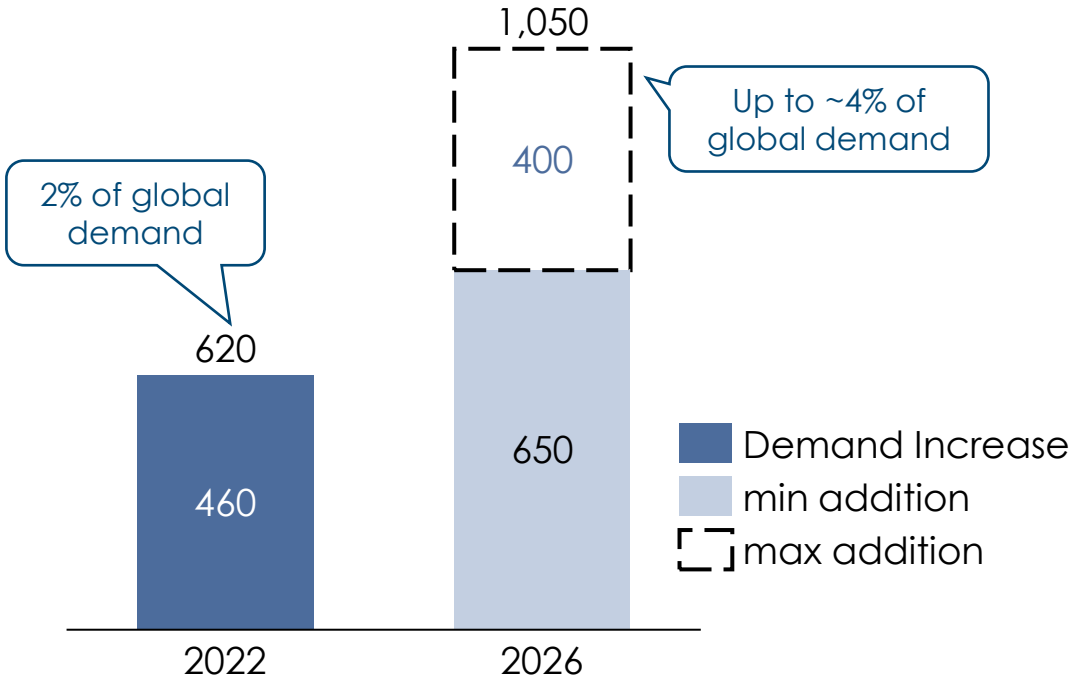
Demand is now entering an era of faster growth, predominantly met by wind and solar, with demand from data centres potentially set to surge

Annual percentage increase in global electricity demand, 2013-2023 (realised) and 2024-26 (IEA forecast), %



Global electricity demand is entering an **era of stronger growth at 3.4%** over 2024-2026

Electricity demand from data centres, 2022 (realised) 2026 (IEA forecast), TWh



Data centres may **double** their share of global electricity demand in 2026

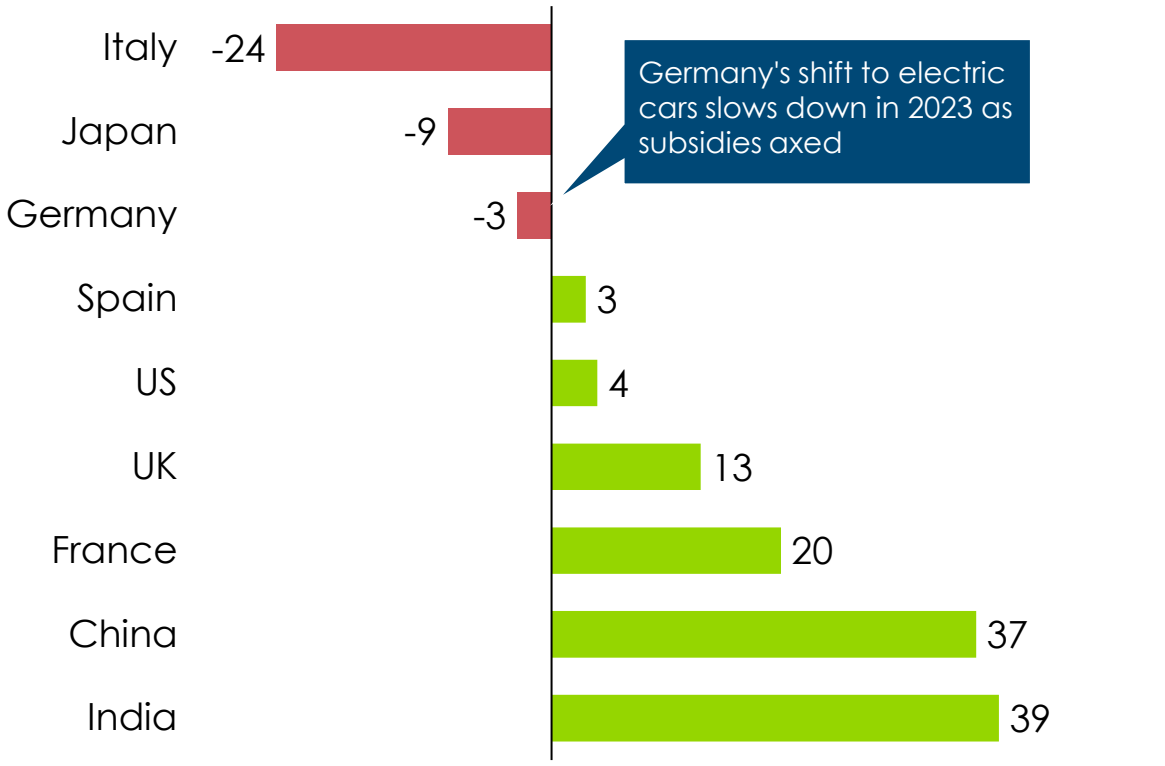
ETC to produce a 'short' on power demand growth in Autumn/Winter 2024

Source: Ember (2024), *Global Electricity market Review 2024*

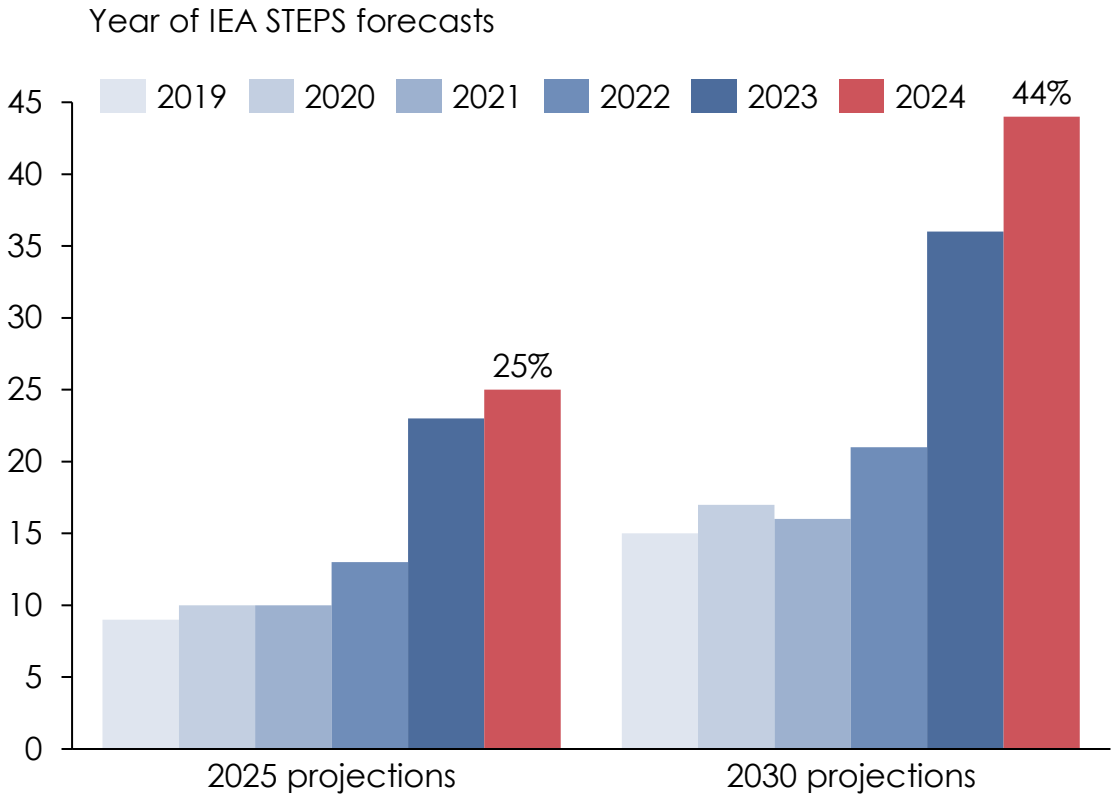
Road Transport

EV sales slow down in some regions, but it's a slow down from very rapid uptake

Passenger EV sale year-on-year change in select countries,
1Q 2024, %



Forecasts of electric vehicle's share of passenger vehicle sales
% of total sales



Similar to Solar: Expectations of EV sales this year are higher than BNEF's projections for 2030 made only two years ago.

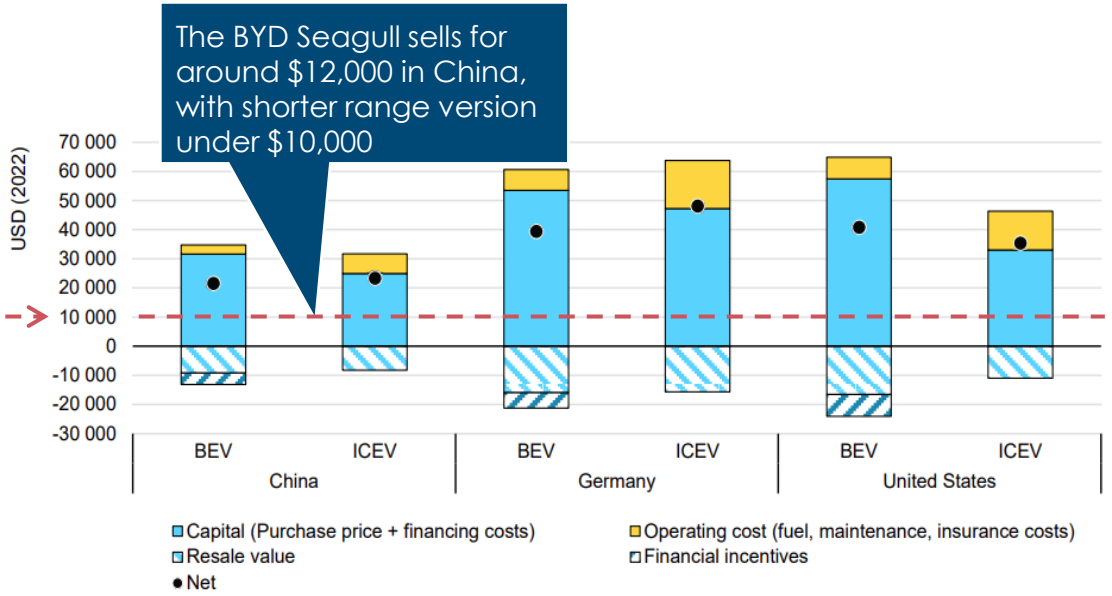
Source: Auke Hoekstra/IEA World Energy Outlooks; Hoekstra et al. (2017), *Creating agent-based energy transition management models…*; BNEF (2023), *Interactive data tool – Global installed capacity*; Hannah Ritchie/IEA Electric Vehicle Outlooks; BNEF (2022), *Long-term electric vehicle outlook*. Bloomberg (2022), *Chinese Oil Giant Brings Forward Its Key Carbon Deadlines;* BNEF (2024), *Electric Vehicle Outlook 2024*

Speed of uptake is dependent on total cost of ownership – the BYD model in China shows that low cost is achievable

BYD, official e-mobility partner of the UEFA EURO2024

Breakdown of the cost of ownership for a sales-weighted average medium-sized battery electric and conventional car purchased in 2022, 5 years after purchase, by country

USD (2022)

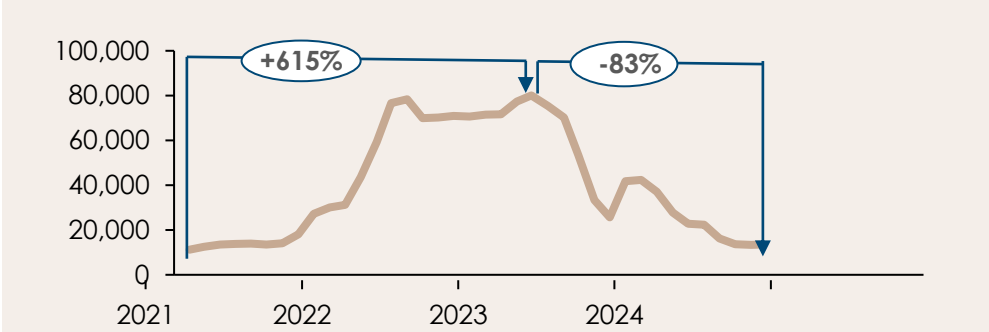


5 years after purchase. Financial incentives include subsidies, vehicle purchase tax exemptions and tax credits. All calculation assumptions are listed in Table 1 located in the general annex of this document.

Sources: IEA (2024), *Global EV Outlook 2024*

Previously, rising battery mineral prices created a bottleneck, but as these prices come down, overall costs should decrease

Lithium, $/tonne

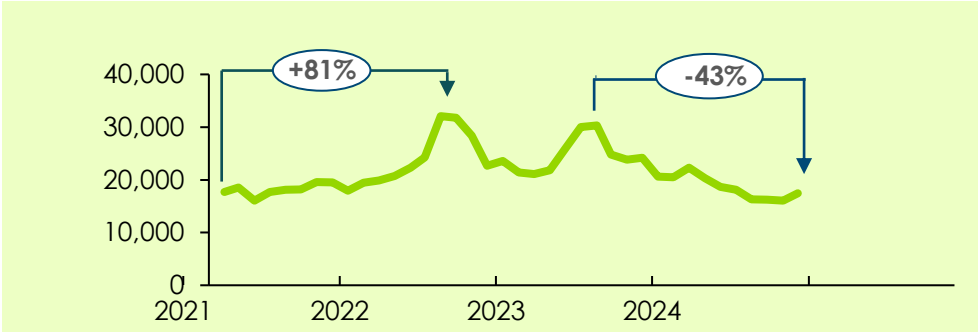


Some slowdown in EV demand relative to high expectations

New projects announced in EU, US, Australia, Chile…some subsequently postponed

New technology: Direct Lithium Extraction (DLI) from brine

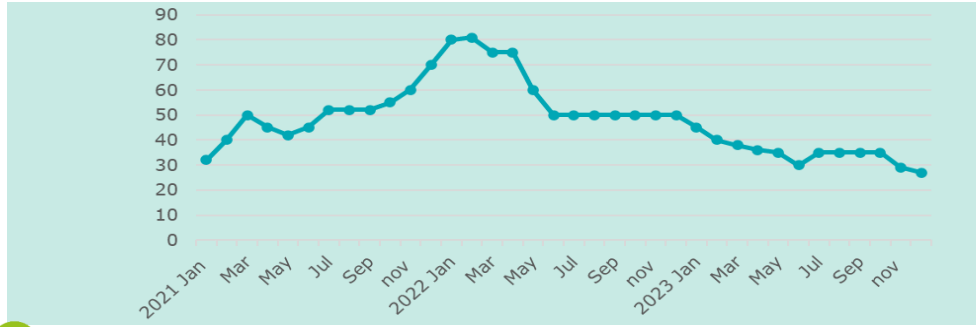
Nickel, $/tonne



Shift towards nickel-free LFP batteries

Massive expansion of Indonesian supply (Chinese owned)

Cobalt, 1,000$/tonne



Reduction of Co proportion within NMC batteries

Shift towards nickel and cobalt free LFP batteries

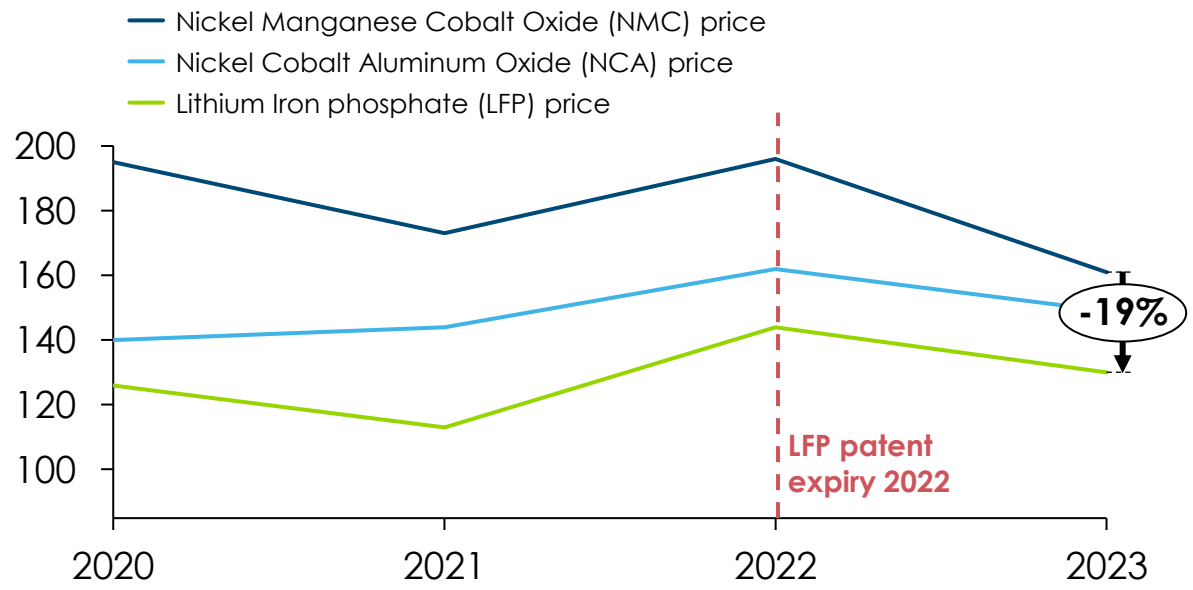
By product of nickel development in Indonesia

Source: BNEF (November, 2023), Lithium-Ion Battery Price Survey.

As the cheapest option, LFP batteries are widespread in China and are expected to soon capture some NMC market share in Western countries

Historical LFP, NCA and NMC pack prices

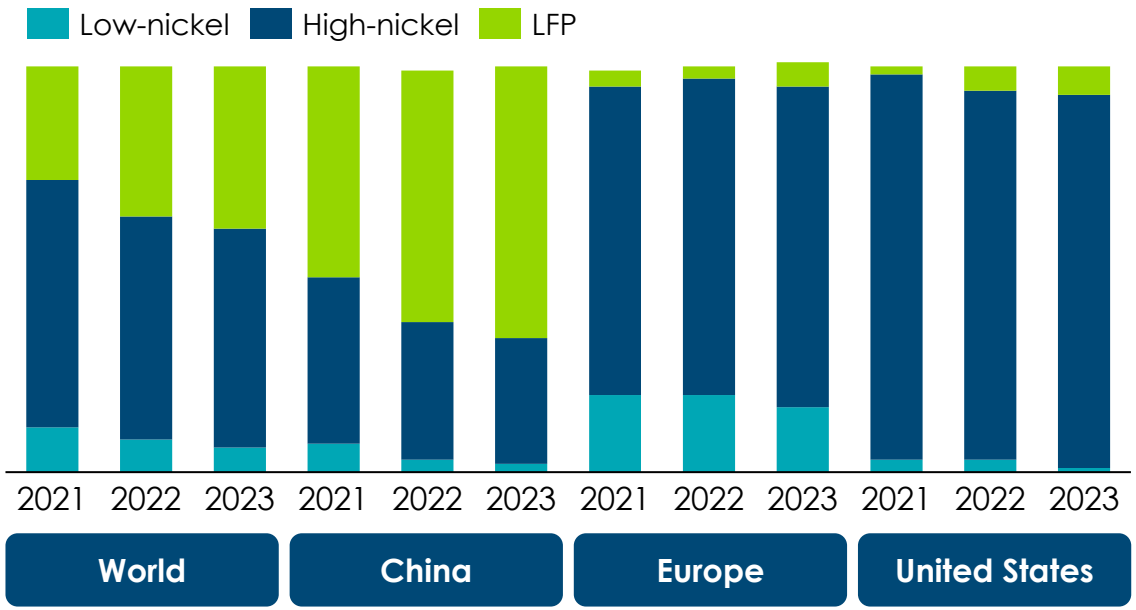
Real 2023 $/kWh



The expiration of core LFP patents in 2022 sparked global interest, leading to significant investments in Morocco, which holds the world's largest phosphate reserves and FTA with the U.S. and the EU.

Share of battery capacity of electric vehicle sales by chemistry and region, 2021-2023

%



Over the past five years, LFP has risen to prominence in the battery industry, supplying over 40% of global EV demand by capacity in 2023, more than double its share in 2020.

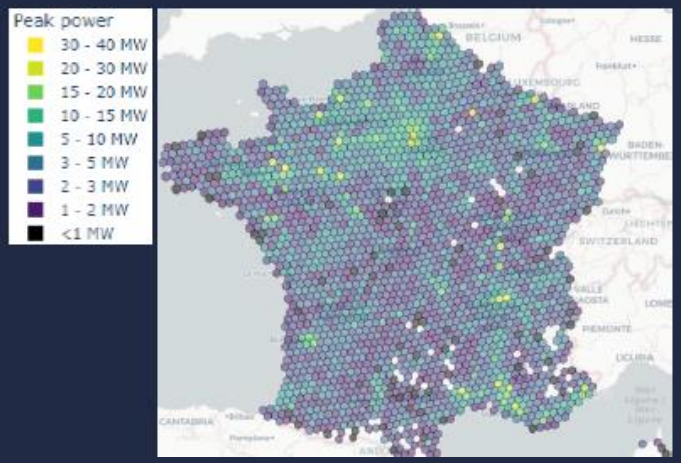
Note: LFP is lithium iron phosphate, NCA is nickel cobalt aluminum oxide, NMC is lithium nickel manganese cobalt oxide. Low-nickel includes lithium nickel manganese cobalt oxide (NMC) 333, NMC442, and NMC532. High-nickel includes NMC622, NMC721, NMC811, lithium nickel cobalt aluminium oxide (NCA), and lithium nickel manganese cobalt aluminium oxide (NMCA)

Sources: Systemiq analysis for the ETC; BNEF (2023), *2023 Lithium-Ion BatteryPrice SurveyPrices falling again;* IEA (2024), *Global EV Outlook*

The availability of charging infrastructures is likely to become a key bottleneck for Heavy Duty Vehicles

Annual public charging installations need in France for 20% rolling truck population

power	#hex
30-40 MW	3
20-30 MW	18
15-20 MW	25
10-15 MW	85
5-10 MW	346
3-5 MW	566
2-3 MW	747
1-2 MW	473
<1 MW	82



>2,000 charging stations with > 1 MW power would be required in France only to meet the demand of 20% electric rolling truck fleet

Dedicated charging for heavy-duty vehicles is the next frontier

- The EU and the US target ~**30% of trucks sold in 2030** to be electric
- New EU regulation obliges member states to install a minimum of one charging hub (350kW+ chargers) every **60-100 km of road.**
- These targets should provide enough charging points to cover the 2030 E-HDV fleet but…
- …there is essentially no public charging infrastructure in place for HDVs currently, and **industry may struggle to ramp up** manufacturing and installation capacity to hit these targets.

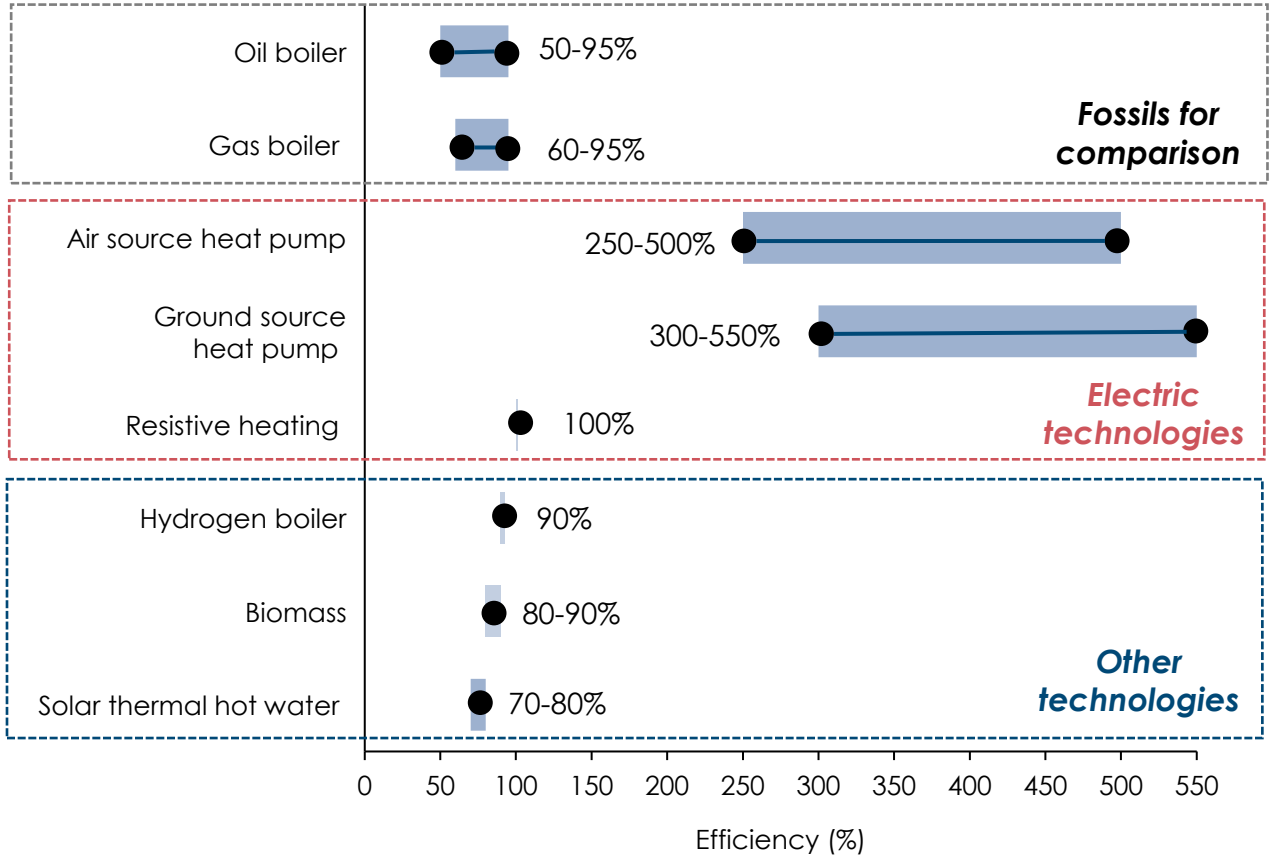
Notes: ETC modelling calculates that 33%-38% of HDVs sold in the EU would be electric in 2030, around 120k-140k.
Source: Systemiq modelling for the ETC; The ICCT (2022), *Biden wants all new commercial trucks to go electric by 2040;* T&E (2024), *EU reaches deal on near phase-out of diesel trucks*

Heat pumps

Heat pumps are a far superior technology, over 3 times as efficient as fossil fuel space heating technologies; they can also decarbonise the 50% of industrial heat which runs on low-medium temperature heat

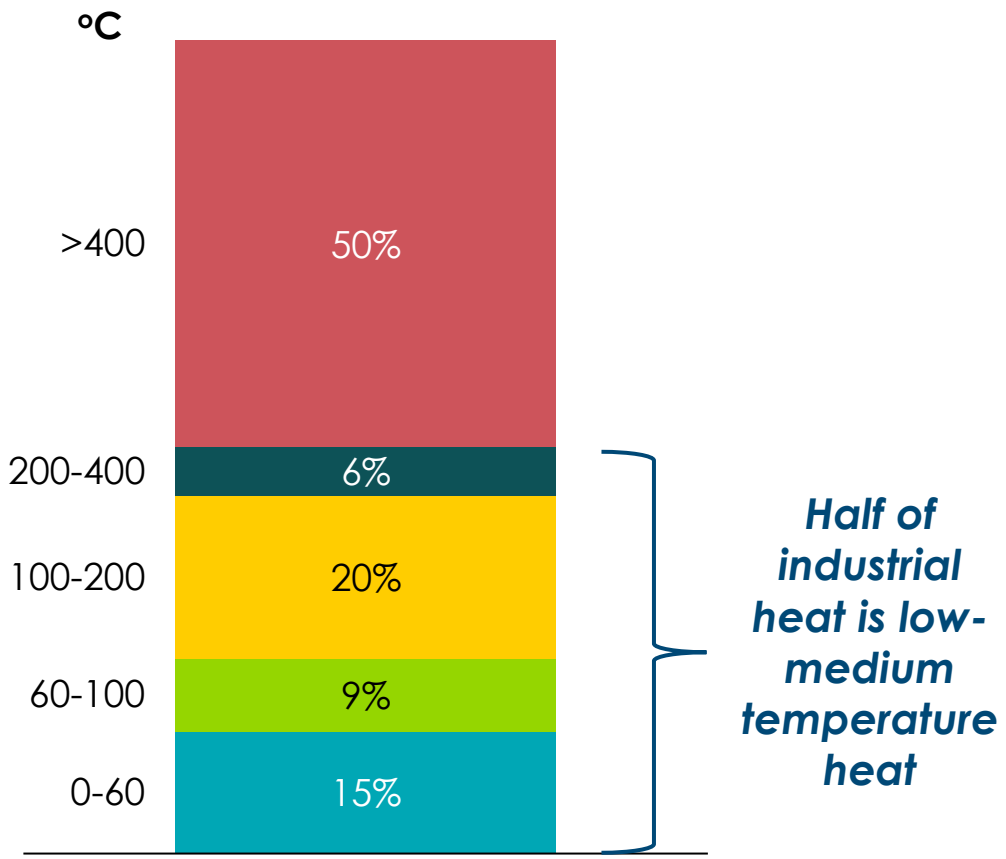
Efficiency of space heating technologies

%



Industrial heat demand by °C

% of total

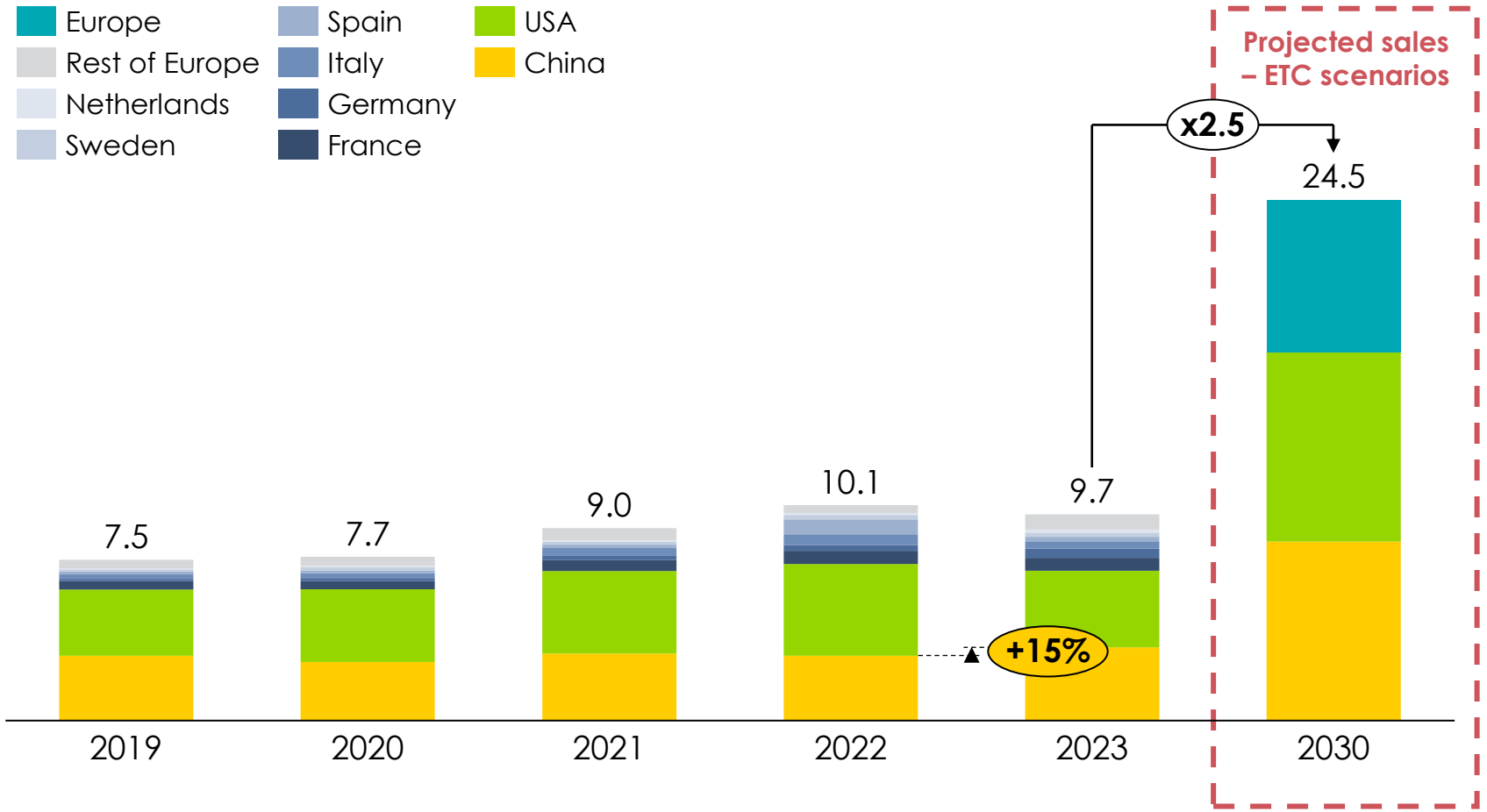


Sources: Systemiq analysis for ETC (2024); IEA (2022), *Future of Heat Pumps;* IRENA (2022), *Heat Pump Market and Costs;* IEA (2021) *NZE.;* IEA (2023), *Energy Efficiency Database.*

European and US heat pump sales hit a plateau in 2023, but kept rising in China; global sales need to more than double by 2030

Heat pump sales across key countries, 2019 – 2030 (buildings)

Million number of units sold per year



What caused a fall in sales in Europe and the US?

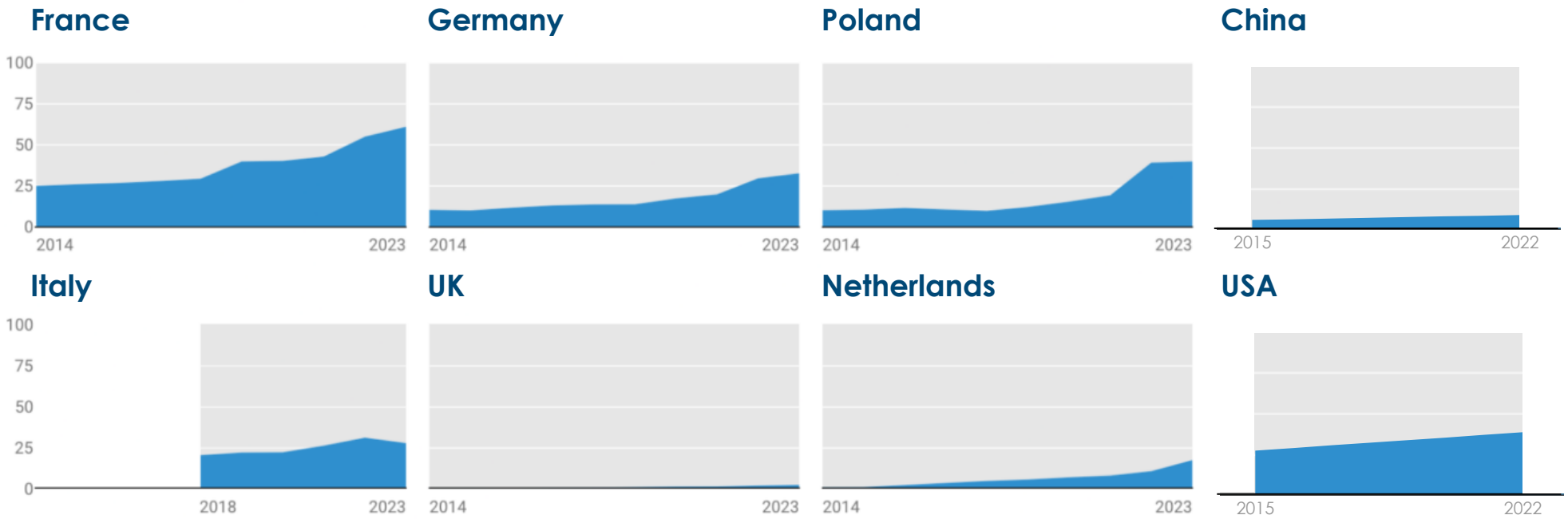
- **Shifts in policy**: potential for higher future subsidies delaying sales (e.g., Austria); reduced subsides in others (e.g., Italy)
- **Falling gas prices:** reduces the payback of heat pumps
- **Cost of living challenges**: global inflation is slowing consumers spending
- **Consumer backlash** e.g., reversing planned regulation in Germany and the UK

Source: ETC (2023), *Fossil Fuels in Transition;* EHPA (2023), *Market statistics*; EHPA (2024), *Pump it down: why heat pump sales dropped in 2023*; IEA (2024), *Heat pump sales in China and in the rest of the world, 2019-2023*; Energy Institute at HAAS (2024), *Why are heat pump sales decreasing?*
Note: 2030 projections for Europe and US are the average of the ETC's 'Ambitious and Clearly Feasible' and 'Plausible but Stretch' scenarios; China is from the IEA.

However, heat pump's market share continues to increase in most key markets, tripling from ~10% in 2013 to ~25% in Europe in 2023

Market share of heat pumps across key countries

% share of heat pump compared with fossil fuel boilers across key markets



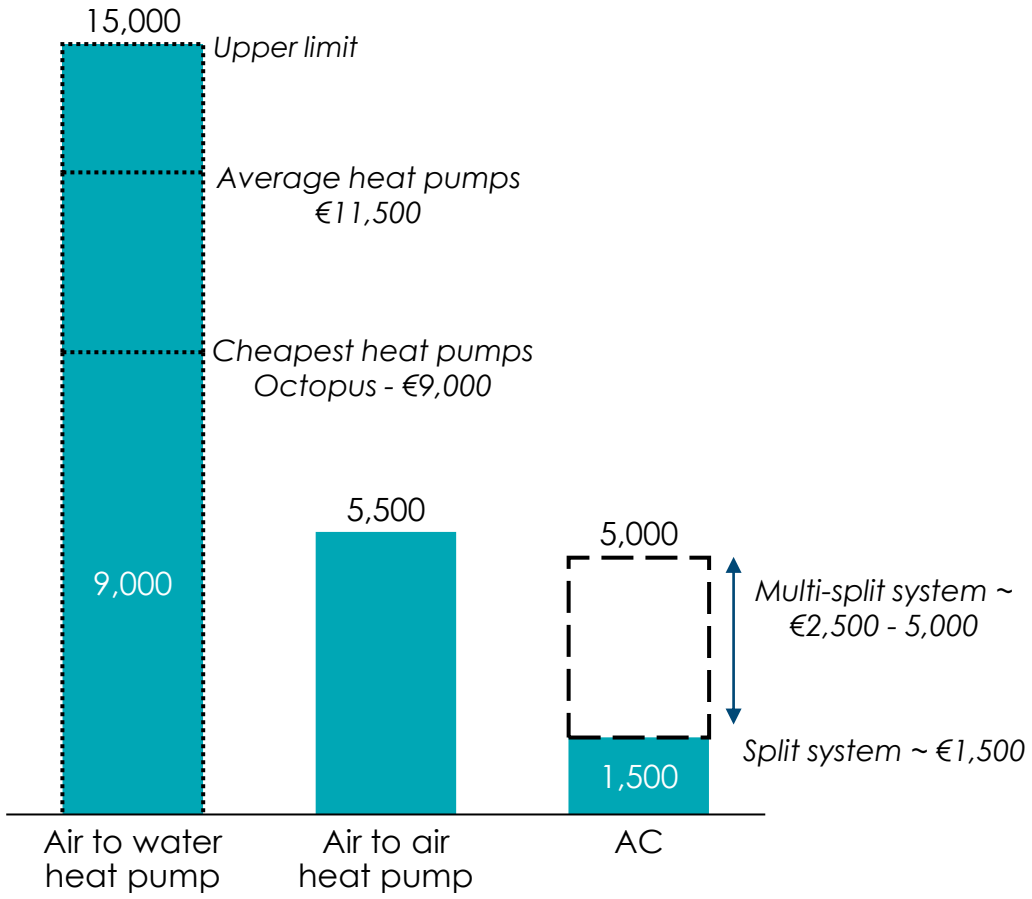
- In France, more heat pumps sold than gas and oil boilers for the first time in 2022
- Heat pumps account for 60% and ~30% of heating tech sales in France/Germany
- In the UK, sales account for <5% and China for 8%

Source: Heat pump sales from EHPA Market Statistics. Sales for boilers from Uniclima (France), BDH and Umweltbundesamt (Germany), SPIUG (Poland), Assotermica (Italy), BRG (Netherlands and UK) and IEA (China and USA). Chart by Carbon Brief

The main barrier to heat pump adoption remains the upfront capex cost; but AC units can be ~3-4 times cheaper than air-to-air heat pumps, suggesting costs can come down

Average capex cost (technology and installation)

€



We are unlikely to see cost reductions on the same scale as solar; but a fall of ~25% by 2030 is feasible - could it be higher?

Key drivers of cost reductions:

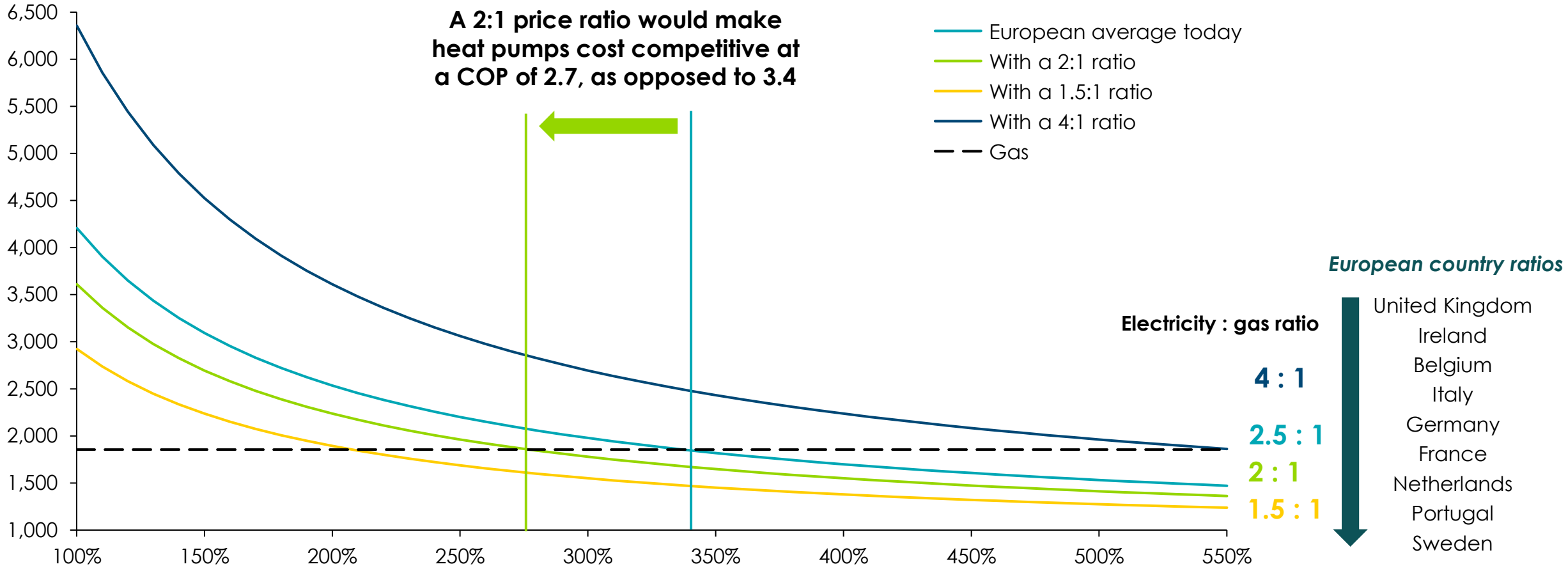
Capex ~40% of costs	Labour ~60% of costs
Heat pumps / ACs are already a mature technology	Installations will improve in quality and speed as installers gain experience
Growing competition and trade as market scales	Huge labour and skills gaps expected
Economies of scale	Subsidies are dampening potential falls in labour costs
Manufacturing capacity constraints – short-term risks, but short lead times of 1-3 years to ramp up	There is no one-size-fits all solution; designing an install will take time
Subsidies are dampening the impact of competition	

Significant driver of cost reductions	Large driver of cost reductions	Unclear / immaterial	Unlikely to reduce costs	Significantly unlikely to reduce costs

Sources: Systemiq analysis for ETC (2024).
Note: figures presented represent the average of costs from ETC literature review. Costs do not include the cost of retrofit measures or any subsidies.

Rebalancing electricity and gas prices is key to driving heat pump uptake, enabling heat pumps to be cost competitive even at lower efficiencies

Equivalent annual costs (capex + fuel costs) at different electricity to gas price ratios
€ a year



Sources: Systemiq analysis for the ETC (2023); Eurostat for Europe electricity and gas prices; Energy Information Administration for US prices.
Note: Assumes an average heat demand of 11,500 KWh a year per household, based on an average across the US and select European countries. Fuel prices reflect averages from 2023. Assumes a discount rate of 5%.

The EU is leading the way with regulation to phase out fossil fuels; the UK and US have no regulation in place, while China plans are ambitious but do not explicitly ban fossil fuels

UK Heat and buildings strategy
Plans for a gas boiler ban in all new built homes *(not regulation yet)*

EU Revised European Building Policy Directive
A gradual phase-out of stand-alone boilers powered by fossil fuels, starting with the end of subsidies to such boilers from 1 Jan

China 14th Five-Year Plan – 2025 targets:

- Plans to construct 50 million m2 of ultra-low or zero-energy consumption buildings in the next 5 years → implying heat pumps as the most low-carbon solution
- Energy consumption caps in building operations
- Increase energy efficiency of new public and residential buildings by 20% and 30%

2025

2026
Requirement for zero emissions for all new public buildings

2028
Zero emissions for all new buildings

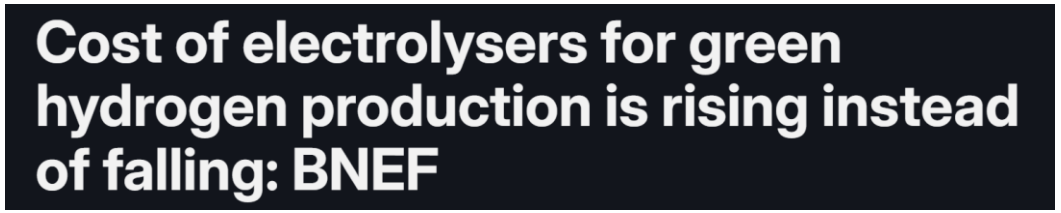
2030
Emission reductions of at least 60% in the building sector compared to 2015

2035
Phase out of fossil fuel based heating systems from all buildings (if not feasible as demonstrated to the Commission, then 2040 at the latest)

Source: Systemiq analysis for ETC based on public policy announcements

Hydrogen

Hydrogen hype is over – scaling up hydrogen is harder than hoped, with rising uncertainty over how useful it will actually turn out to be



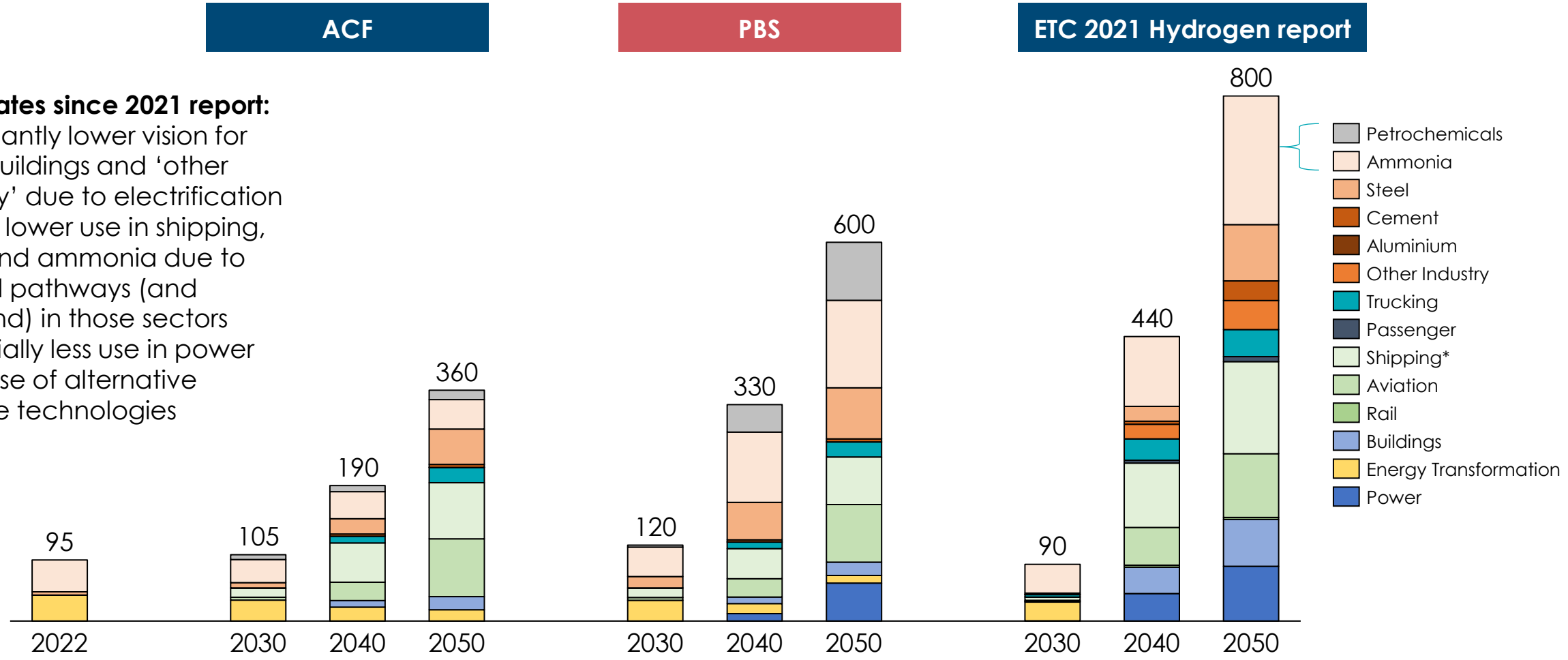
Source: Forbes (2024), *Green Hydrogen's Hype Hits Some Very Expensive Hurdles*; The Guardian (2023) *The Guardian view on hydrogen hype: it's perhaps not as green as you think*; Financial Times (2024), *Lex in depth: how the hydrogen hype fizzled out*; IEEFA (2023), *Blue Hydrogen: Not clean, not low carbon, not a solution*

Hydrogen demand in the ETC's new scenarios is slightly lower than previous estimates, but still 3-6x higher than current

Hydrogen demand by sector, in million tons of hydrogen (MtH_2) per annum

Key updates since 2021 report:

- Significantly lower vision for H2 in buildings and 'other industry' due to electrification
- Slightly lower use in shipping, steel and ammonia due to refined pathways (and demand) in those sectors
- Potentially less use in power because of alternative storage technologies

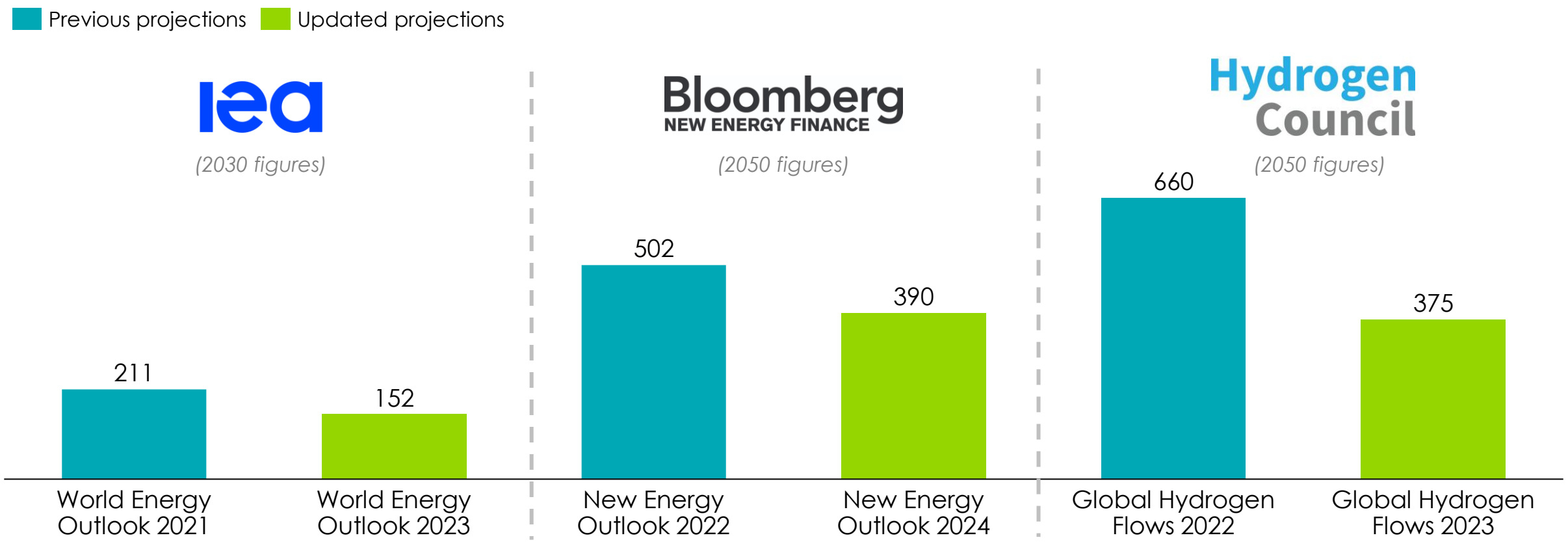


Note: ammonia does not include ammonia/hydrogen used in shipping, which is accounted for separately under 'Shipping', hydrogen consumption from trucking comes from MPP (2022), *Making Zero-emissions trucking possible,* Energy transformation = energy consumed in processing raw fossil fuels into useable energy products, mostly to convert crude oil to refined oil products. ACF=Accelerated but clearly feasible, PBS = Possible but stretched. Source: Systemiq analysis for the ETC (2023).

Other key bodies have also revised down hydrogen projections

Global hydrogen demand in 2030 (IEA) or 2050 (BNEF and Hydrogen Council)

Mt H2

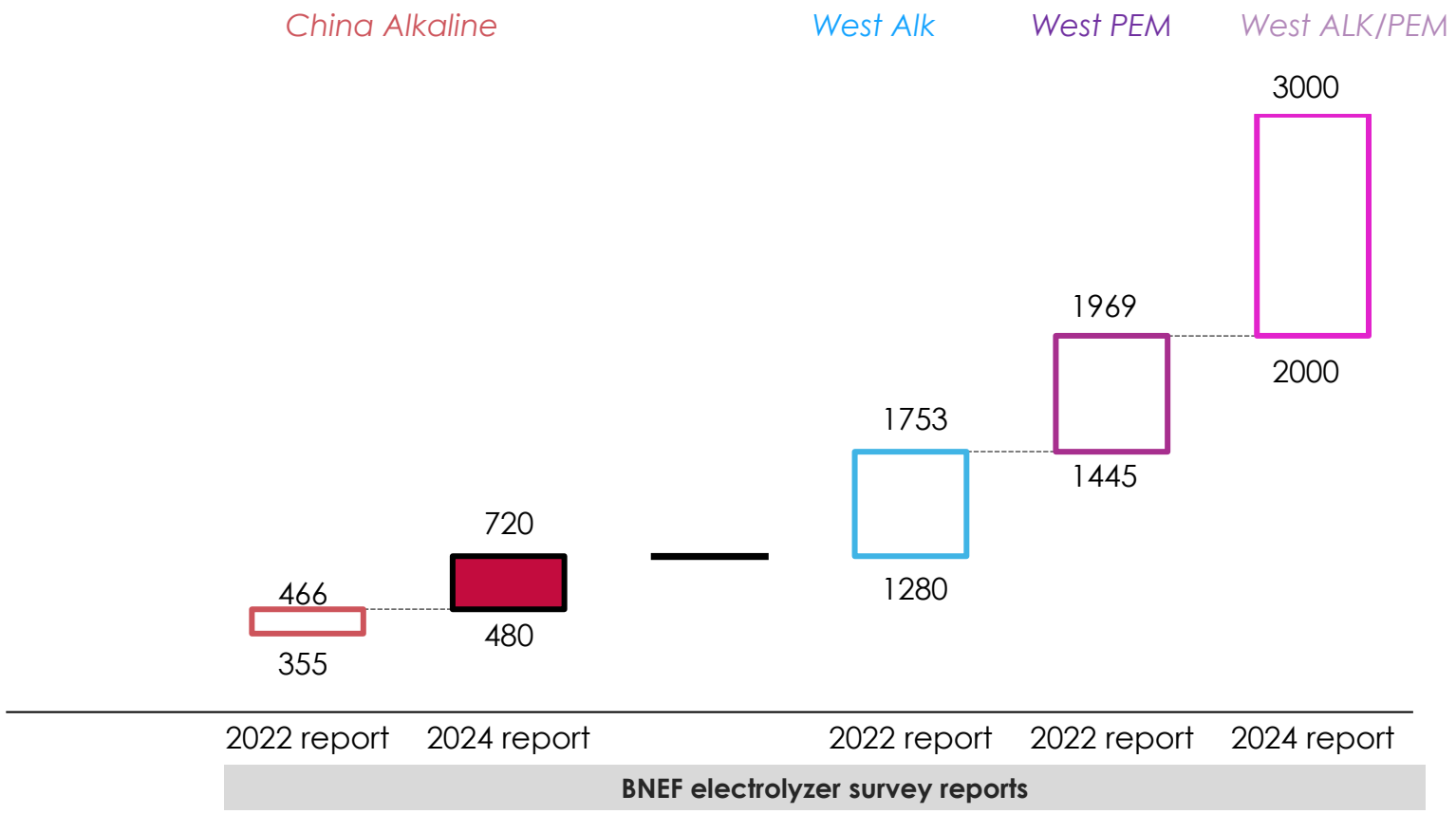


Source: IEA (2023), *World Energy Outlook 2023*; IEA (2021), *World Energy Outlook 2021*; Hydrogen insights (2024), *'Getting to net zero will need nearly a quarter less clean hydrogen than we initially predicted': BNEF*; Hydrogen insights (2023), *Half of all clean hydrogen produced globally could be transported long-distance by 2030, says Hydrogen Council*

Electrolyser prices have increased dramatically over the past years, and significant progress needs to be made to drive down costs of hydrogen by 2030

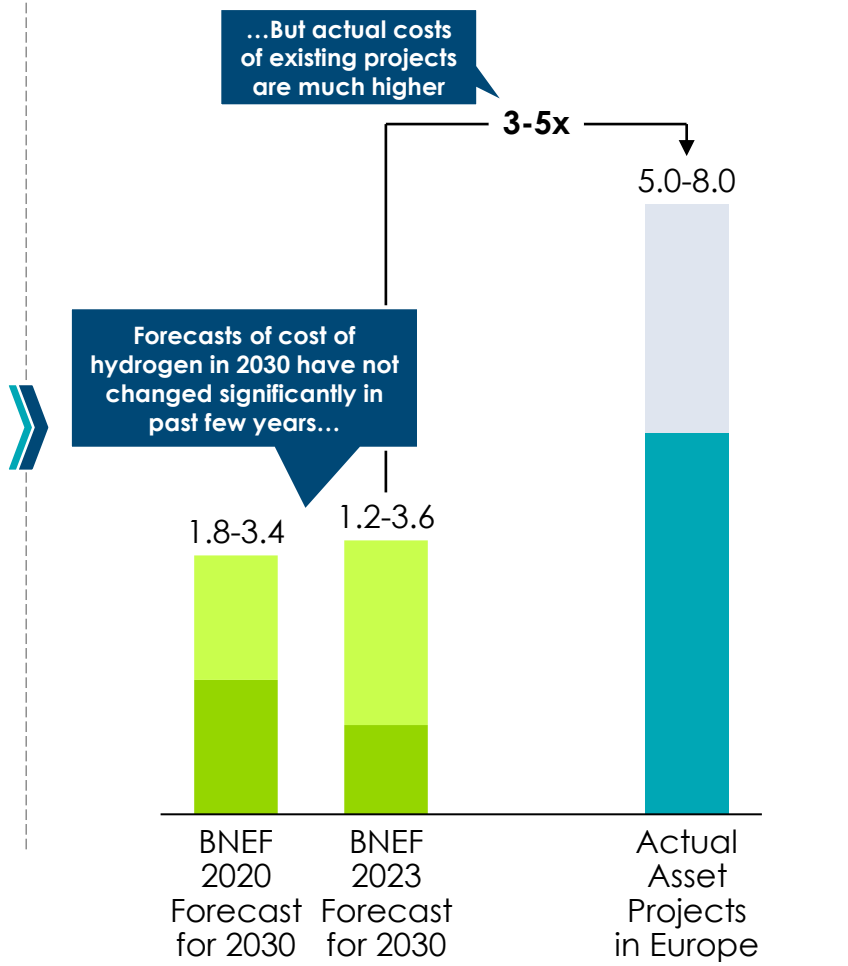
System capex forecast of large alkaline electrolysis projects

$/kW



Levelised cost of hydrogen

$/kg hydrogen



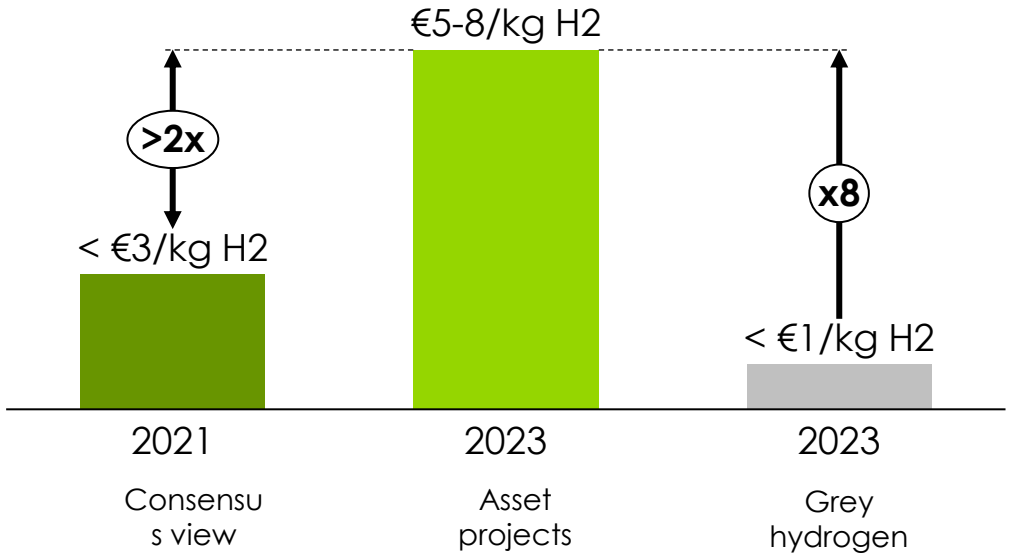
Note: ALK = Alkaline Electrolyser. P

Source: Systemiq analysis for the ETC; BNEF (2024), Electrolyzer Price Survey 2024: Rising Costs, Glitchy Tech

End of the cheap clean hydrogen myth: green H_2 costs eight times more than grey hydrogen today, with a significant shortfall of trillions in funding

Green hydrogen wholesale price projections in Europe in 2023

€/kg H2

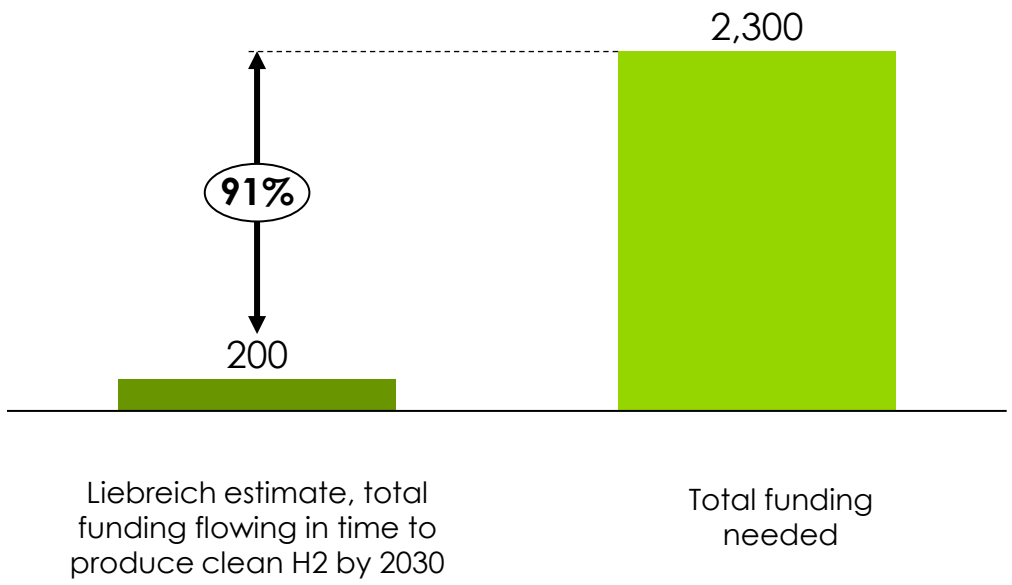


Driving factors for cost increase versus past consensus view:

- Higher capital costs
- Fewer electrolyzer full-load hours
- Supply chain constraints
- Complex "real-life" electrolyzer system
- Lacking infrastructures

Clean hydrogen financing gap to reach 90Mt by 2030,

US$ bn.



Only few sectors are still considered as sensible clean hydrogen use cases:

- Refineries
- Fertilizers
- Green steel
- Shipping and aviation

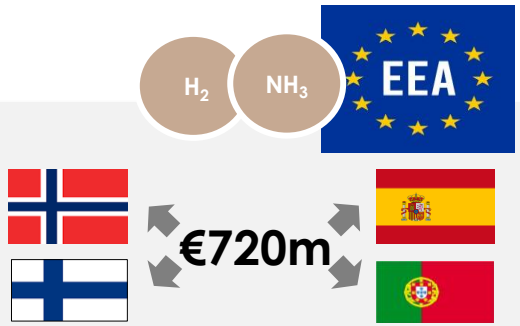
The $2.3 trillion gap assumes 90Mt of clean hydrogen by 2030, with a $2/kg cost penalty for 40Mt of existing uses and $3/kg for 50Mt of new uses, totaling $230bn annually. Using a 10-year offtake agreement, this totals $2.3 trillion needed before 2030 to finance the projects.
Sources: Systemiq analysis for the ETC; BNEF (2023), *Liebreich: Clean Hydrogen's Missing Trillions;* BCG (2023), *Turning the European Green Hydrogen Dream into Reality: A Call to Action;* HydrogenInsights (2024), *EU hydrogen targets are 'impossible' as green H2 costs eight times as much as grey H2 today: Total CEO*

EU Hydrogen Bank: first auction successful, securing funds to achieve 10% of 2030 domestic EU green hydrogen production target

Financial Result

10% of REPowerEU Ambition for H2 covered – if winning projects will be fully realised.

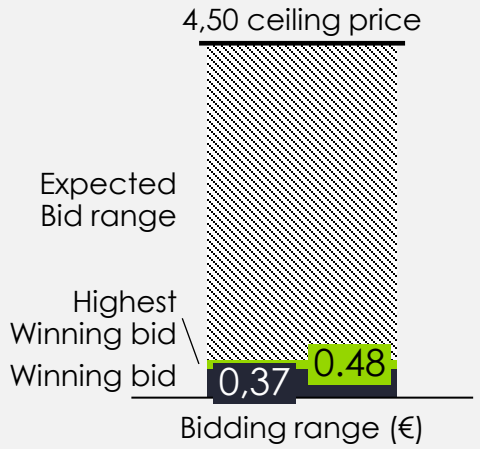
132 competing bids from across the European Economic Area (EEA) resulted in allocation of **€720 million to seven renewable hydrogen and ammonia projects** in Spain, Portugal, Norway, and Finland.



Key Learnings

Strong willingness to produce green hydrogen at unexpectedly low costs.

Winning bids ranged from €0.37-0.48 per kg, well below auction's €4.5 price ceiling.



All winning bids came from countries with abundant renewable energy.

Uneven playing field concerns to incentiize H2 production across EEA.

High price premium for unsuccessful bidders…

…as result of bids driving down price level for hydrogen production.

Larger budgets will be needed…

…in future auctions to boost hydrogen production incentives.

Next auction

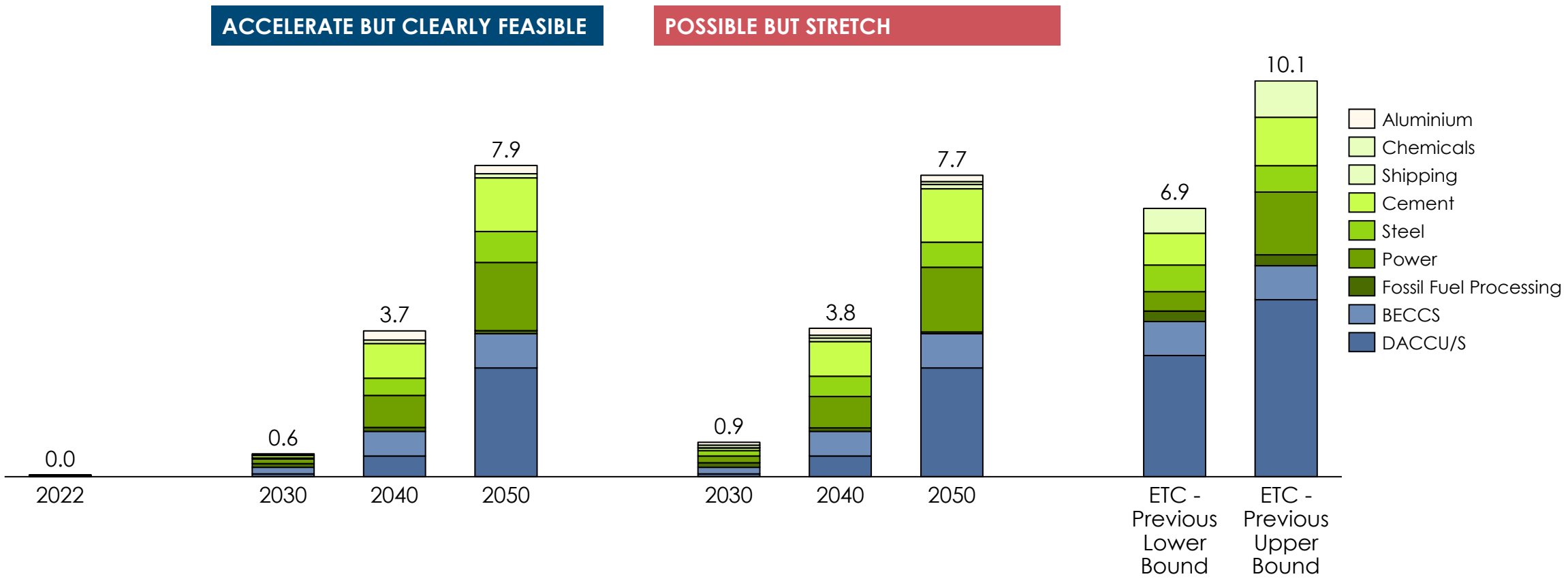
European Commission will launch second auction (worth €2.2bn) in automn 2024.

Source: European Commission (2024), *European Hydrogen Bank pilot auction: 132 bids received from 17 European countries;* Hydrogen Insight (2024), *Exclusive, Second EU hydrogen auction worth €2.2bn set to be delayed to automn 2024*; Ammonia Energy (2024), *Taking the market's temperature: European Hydrogen Bank awards €720 million*.

CCS

Projected CCS capacity in the ETC's updated scenarios ends up at 7-9 $GtCO_2$, in line with previous ETC estimates

CCUS demand by sector, $GtCO_2$



More CCS in power, steel and shipping, as well as for fossil fuel processing.

Lower CCS use in chemicals sector vs. ACF, slightly less CCS in steel and power, same amount of BECCS and DACCS for removals.*

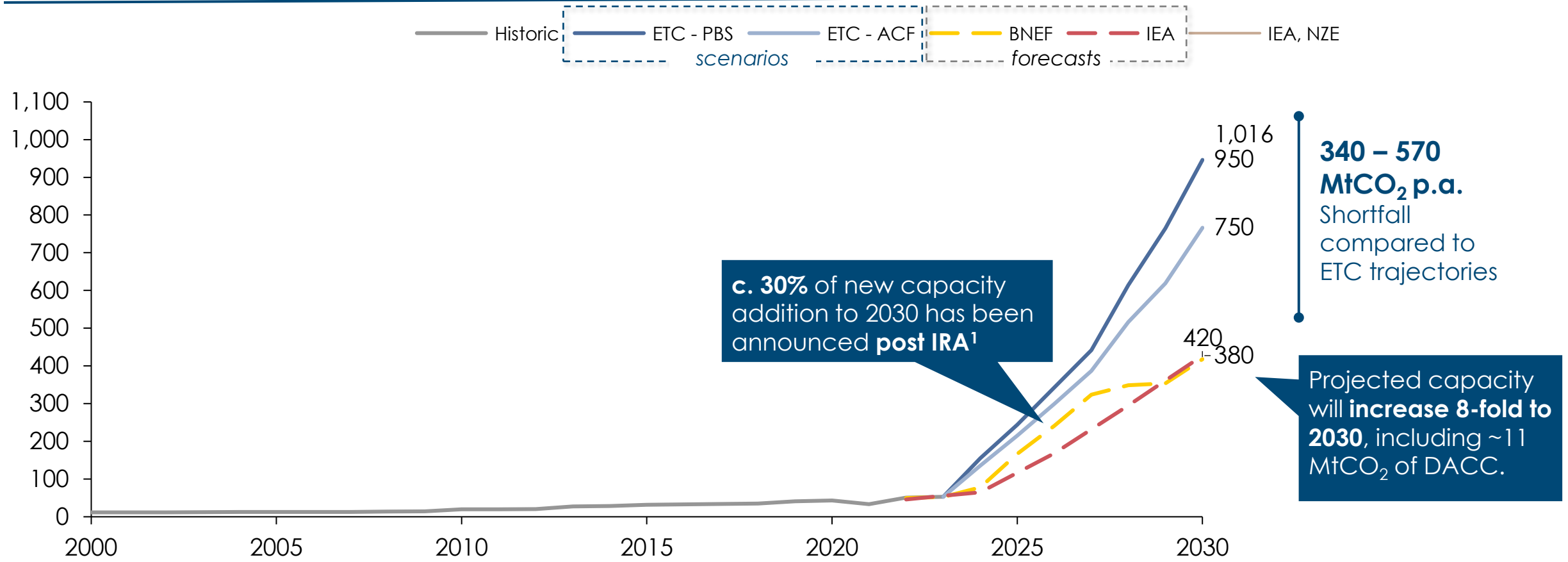
Previous ETC upper bound assumed less CCS for cement and chemicals, but more DACC for aviation and removals.

Note: total captured emissions include both utilized carbon and carbon that is permanently stored. *Volumes in ACF and PBS are same as 'ETC – Previous Lower Bound'.
Source: Systemiq analysis for the ETC (2023); ETC (2022), *Carbon capture, utilization and storage in the energy transition*.

Projected CCUS capacity to 2030 includes ~8x growth from current levels, but falls well short of what is required for ETC's new pathways

Total Carbon Capture Utilisation and Storage (CCUS) capacity to 2030

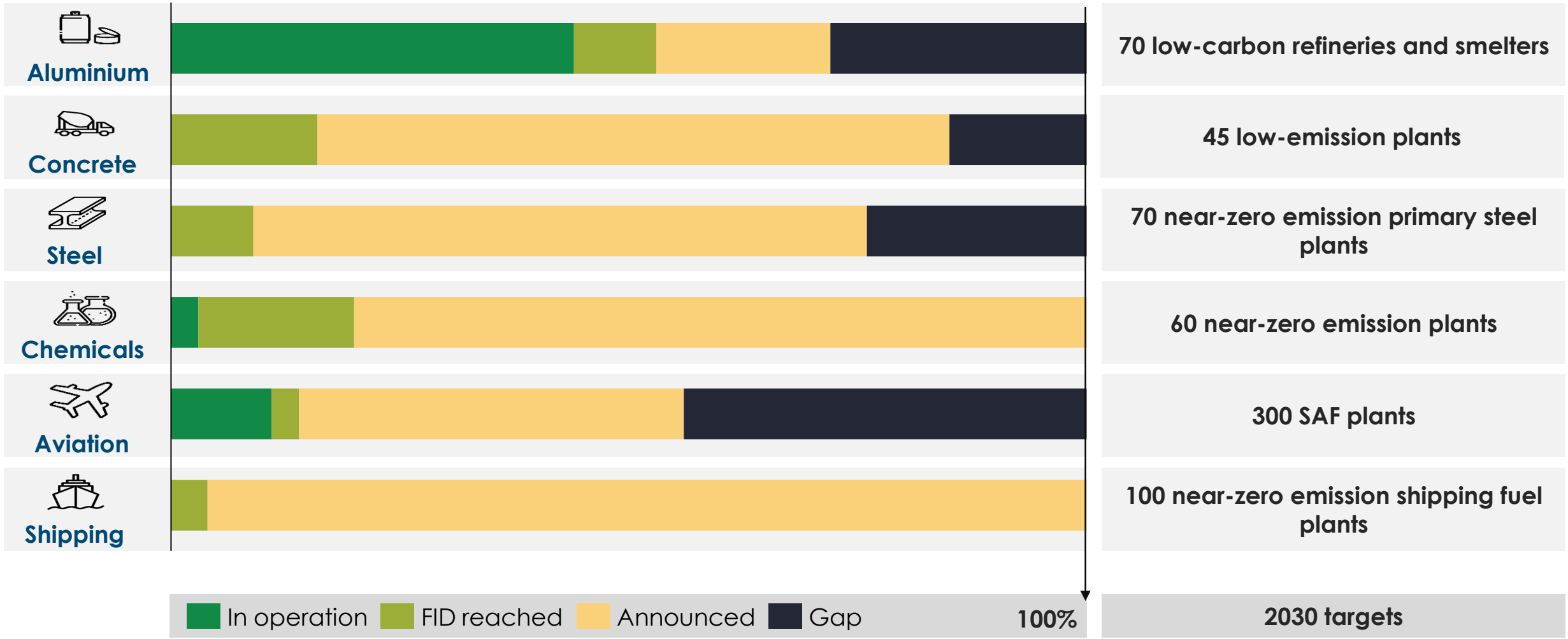
$MtCO_2$ p.a.



Note: [1] IRA = Inflation Reduction Act. The values presented here based on BNEF/IEA include direct air carbon capture (DACC) projects, but the volumes by 2030 are expected to be very low, 10-15 $MtCO_2$ p.a. of capacity. Values are rounded.
Source: Systemiq analysis for the ETC; BNEF (2024) *CCUS Projects Database 1h 2024;* IEA (2024), *IEA, Capacity of current and planned large-scale CO2 capture projects vs. the Net Zero Scenario, 2020-2030,* BCG (2023), *Impact of IRA, IIJA, CHIPS, and Energy Act of 2020 on Clean Technologies*

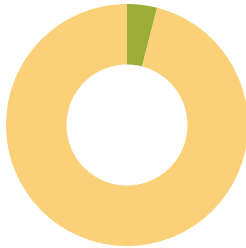
Part 3. Hard to abate sectors

Heavy Industry: Good progress for steel, aluminium and chemicals/ammonia, but decarbonising concrete and aviation remains slow



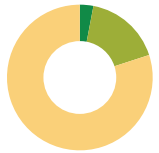
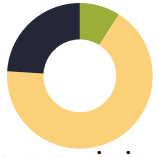
Source:; Mission Possible Partnership (2024), *Global Project Tracker.*

Summary of progress in long-distance transport sectors

Sector	Progress in 2023 & 2024	2030 project stocktake	Summary
Aviation	▪ **Global community tightens goals.** ICAO (UN agency) announces 5% emission cut target by 2030, to spur its 2050% net-zero target. ▪ **Plant projects take off across the world,** picking up steam in India and MENA, while advanced economies boost established projects with more research aid and tax incentives, such as the US IRA SAF Grand Challenge.	 300 SAF plants needed	**2023 SAF production doubled to 0.5 Mt**, now 0.2% of total jet fuel but persistent cost premium complicates reaching targets like EU's 2025 2% quota. Lack of ambitious policies in major markets, esp. China.
Shipping	▪ **Global community set net-zero target.** IMO (UN agency) agreed on shifting from low-ambitious 50% target to net-zero "around 2050" goal. ▪ **About half of 2023 vessel orders for alternative fuels,** with methanol gaining increasing traction against LNG and ammonia orders having "marked a breakout year".	 100 near-zero emission shipping fuel plants needed	**Rising zero-emission fleet orders signal growing industry confidence** in optimal technology choice, with announced projects exceeding MPP 2030 target.

Source: Aviation: Airbus (2024), *Sustainable Aviation Fuels;* ICAO (2023), *Global Framework for SAF.* Shipping: Clarkson & DNV (2024), *Alternative Fuel Insight, Global Shipping Tracker;* MPP (2024), *Global Project Tracker*
Note: vessel order numbers by tonnage,

Summary of progress heavy industry sectors

Sector	Progress in 2023 & 2024	2030 project stocktake	Summary
Cement /concrete	▪ **New partnership to act on 90% of global production.** Global Cement and Concrete Association and China Cement Association (50% alone) work on industry roadmap for action in 2024-2026.	 45 low emission cement plants needed	**Industry takes increasing action, independent from policy action** that focuses on limited geographies, incl. EU carbon border taxation (CBAM) or US IRA.
Aluminium	▪ **Technology progress** in clean energy and CCS integration; e.g. Rio Tinto announcing major progress on carbon-free smelting. ▪ **Plant projects take off globally.** Major players such as China's Chalco (10% global market share) and Vedanta, announcing substantial investments.	 70 low-carbon refineries and smelters needed	**Projects gain momentum** thanks to industry investment initiatives, reacting on government targets (e.g. CBAM).
Ammonia	▪ **Major capacity additions across global regions, with India poised to become global production hub** as major local industries join forces to create production clusters.	 60 green and blue ammonia plants needed	**Industry on track,** with global plant announcements exceeding MPP 2030 targets.
Steel	• **Major technology progress** e.g. by ArcelorMittal (no 2 worldwide) in hydrogen production processes. • **Launch of ambitious national** to accelerate green steel transition; e.g. US Clean Steel Initiative.	 70 near-zero emission primary steel plants needed	**Technology advancements clash with costly production conditions for scale-up**(Europe), while key regions like China fall behind in meeting green steel targets.

Source: Cement: Global Cement and Concrete Association / China Cement Association (2024), China and Global cement agreement on low-carbon future – Milestone partnership launched to deliver sustainability of the world's essential material; Aluminum: Chalco (2023), *Investor Relations;* Rio Tinto (2023), *Carbon-free aluminum smelting is a step closer;* Ammonia: Chemical Industry Digest (2024), *India Aims for Global Leadership in Renewable Ammonia.* Steel: Reuters (2024), *China lags in efforts to achieve 2025 green steel goals, analysts say;* GMK Center (2024), *Green hydrogen is too expensive for ArcelorMittal Europe's plants – CEO;* MPP (2024), *Global Project Tracker*

Direct electrification technologies are emerging, showing increasing potential against frontrunning solutions to decarbonize heavy industry high-temperature processes.

	Frontrunning decarbonization technology*	Direct electrification alternative	Key companies	Key challenges	Potential of direct electrification alternative
Aluminium	**Low-carbon anode (esp. Inert anodes) & Hydrogen Calcination.**	**Electrochemical metal oxide electrolysis** use high electric current or plasma to create high temperature for activating direct chemical conversion of aluminum oxide into aluminum.	BOSTON METAL	**Low development state** • Not in focus of major producers. **Challenging operations** • Requires significant green electricity **Manufacturing scalability challenges** • Need for costly high temperature resistant material.	**Major economic advantage,** from streamlined production, like omitting smelter production step.
Steel	**Hydrogen-based direct induced iron (DRI).**	**Electric arc furnaces (EAF)** use high electric current to create plasma, forming an arc between the electrodes to melt scrap steel or direct reduced iron (DRI) at high temperature.	NUCOR TATA STEEL SSAB ArcelorMittal	**Challenging operations** • Process requires significant green electricity supply. • Relies on availability of scrap steel or DRI which can fluctuate.	**Presents notable economic advantages,** arising from relative high energy efficiency, feedstock flexibility, lower initial investment requirements and scalability.
Low – medium temp industry	**High temperature heat pumps**	**Heat pumps** which utilise waste heat from industrial processes or cascade systems to reach higher temperatures	TRANE TECHNOLOGIES DAIKIN	**Constant and reliable temperature required:** challenge of relying on variable renewables → heat storage key **Cost:** upfront capex and electricity/gas price ratio **Awareness and early demand**	**Significant efficiency gains** – huge operating cost benefits with rebalanced energy prices

Impact on MISSION POSSIBLE PARTNERSHIP **Direct electrification alternatives might challenge MPP's decarbonization pathways via its frontrunning decarbonization technology.**

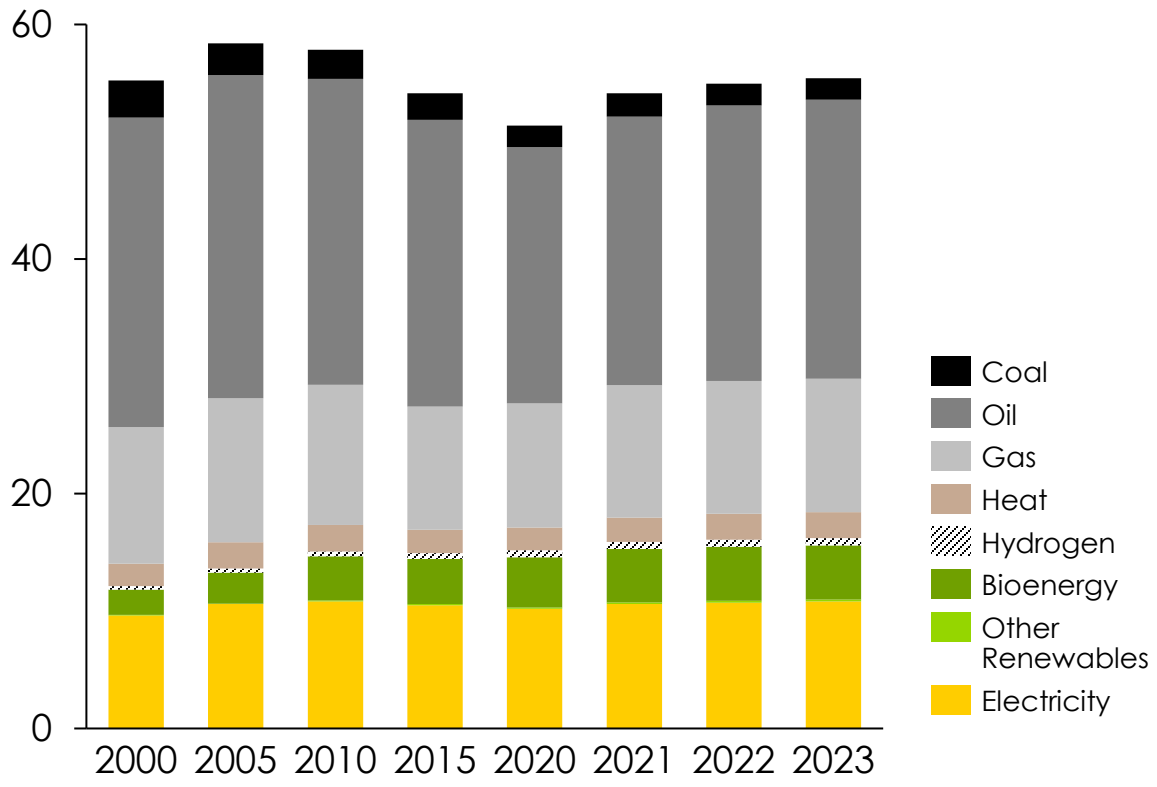
Source: Mission Possible Partnership (2022), *Cement/Aluminum/Ammonia/Steel Sector transition strategy reports;* Logos from respective company websites (2024).
Note: *MPP focus technology: raising question if they could be challenged; Listing on this slide does not include CCU/S technologies.

Part 4. Regions

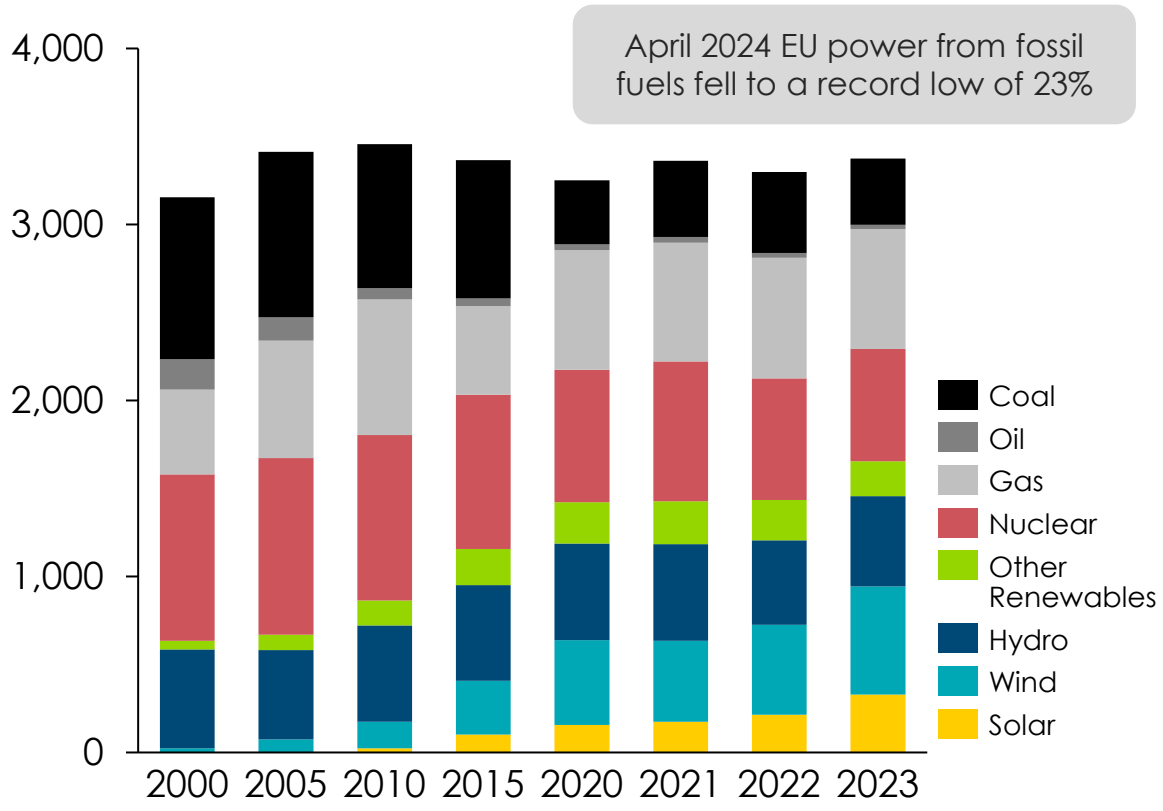
EU

In 2023, renewable generation surpassed 40% and wind generated more electricity than gas (for the first time)

Final Energy Demand by Fuel (PJ)

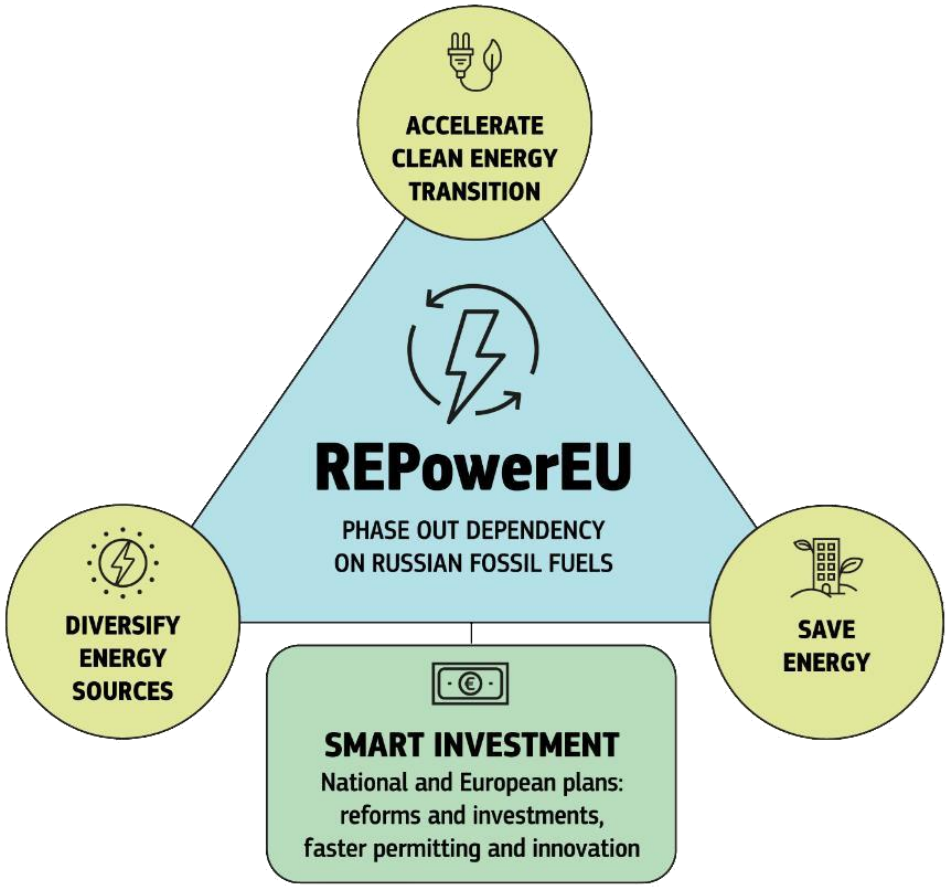


Power generation by technology (TWh)



Source: BNEF World Energy Outlook 2023

REPower EU has greatly accelerated the move away from Russian gas



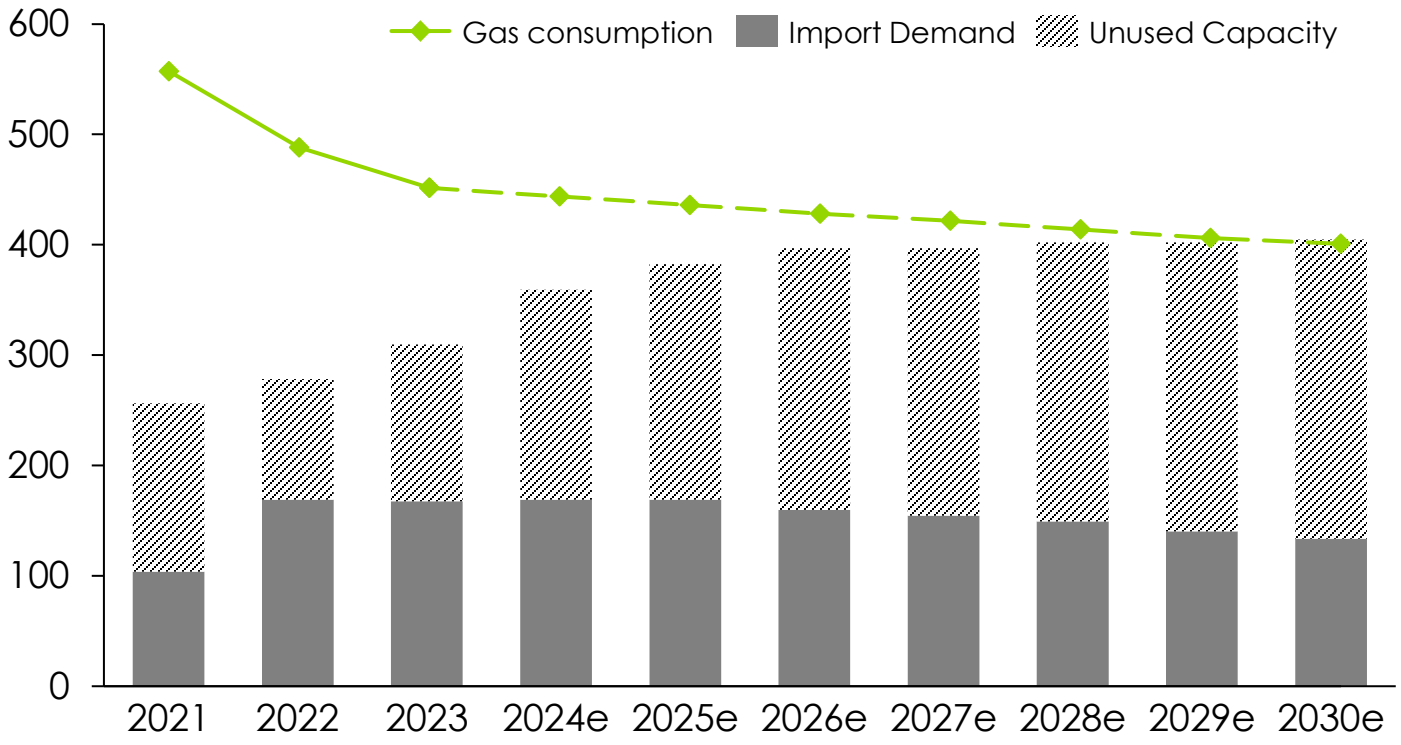
- Reduced gas consumption by 125 bcm (18% or approximately 1200 TWh)
- Overcome dependency on Russian fossil fuels (45% of imported gas in 2021 from Russia v. 15% in 2023)
- Ensured access to secure and affordable energy
- Produced more electricity from wind and solar than from gas for the first time ever
- Rapidly increased renewable energy installation

Source: EU Commission REPowerEU website

Europe's LNG capacity buildout outpaced demand but new gas terminals are still getting approved and coming online

LNG consumption v. import demand and capacity, 2021-2030

Billion cubic meters (bcm)



Less gas being consumed means less gas imports: while import capacity forecasted to meet total consumption, average utilization rate expected to be well-below 50%

Source: IEEFA "Europe's LNG capacity buildout outpaces demand" (October 2023)

Institute for Energy Economics and Financial Analysis

Europe's gas consumption falls to 10-year low as peak LNG demand nears

21 February 2024 (IEEFA) | Europe's gas consumption in 2023 fell to its lowest level in 10 years as countries scale up efficiency measures...

21 Feb 2024

Euractiv

Bratislava to build its first LNG terminal despite fossil fuel phase out

Fears that Slovakia's liquefied natural gas (LNG) terminal could end up as a stranded investment are reinforced by experts who warn that too...

09 Jan 2024

Reuters

Germany's Mukran LNG terminal receives operating permit

Germany's Baltic Sea import terminal for liquefied natural gas (LNG) at Mukran on Ruegen island has received its operating permit under...

10 Apr 2024

The Brussels Times

Belgium on track to open new gas power plant in Liège

It will be one of the largest turbine-gas-steam plants in the world with power for more than one million homes each year.

1 month ago

Ambitious sectoral policies are setting clear pathways for decarbonisation of transport and buildings by 2050 – industry set to plateau

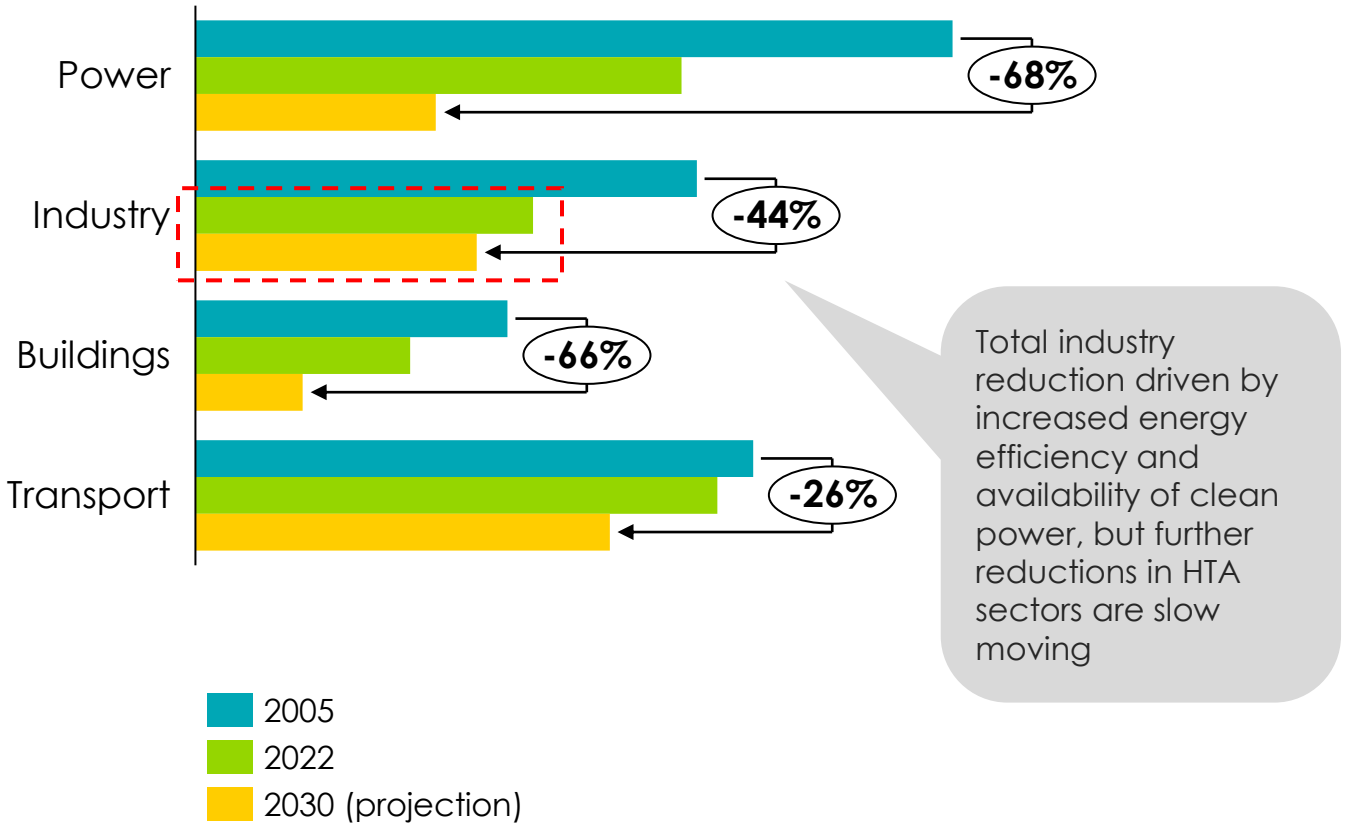
Key new or revised policies since January 2023

By sectors and cross-cutting technologies

Sectors	**Power**	Offshore wind action plan, Electricity Market Design Reform
Sectors	**Industry**	Net Zero Industry Act
Sectors	**Buildings**	Energy Performance of Buildings Directive
Sectors	**Transport**	Fuel EU Aviation, ReFuelEU Maritime, Alternative Fuels Infrastructure Regulation
Technology	**Hydrogen**	European Hydrogen Bank, relaxation of State aid rules
Technology	**Carbon removals and CCUS**	Industrial Carbon Management Plan, Carbon Removal Certification Framework

GHG emissions from energy in the EU, 2005-2030

$GtCO_2e$/year

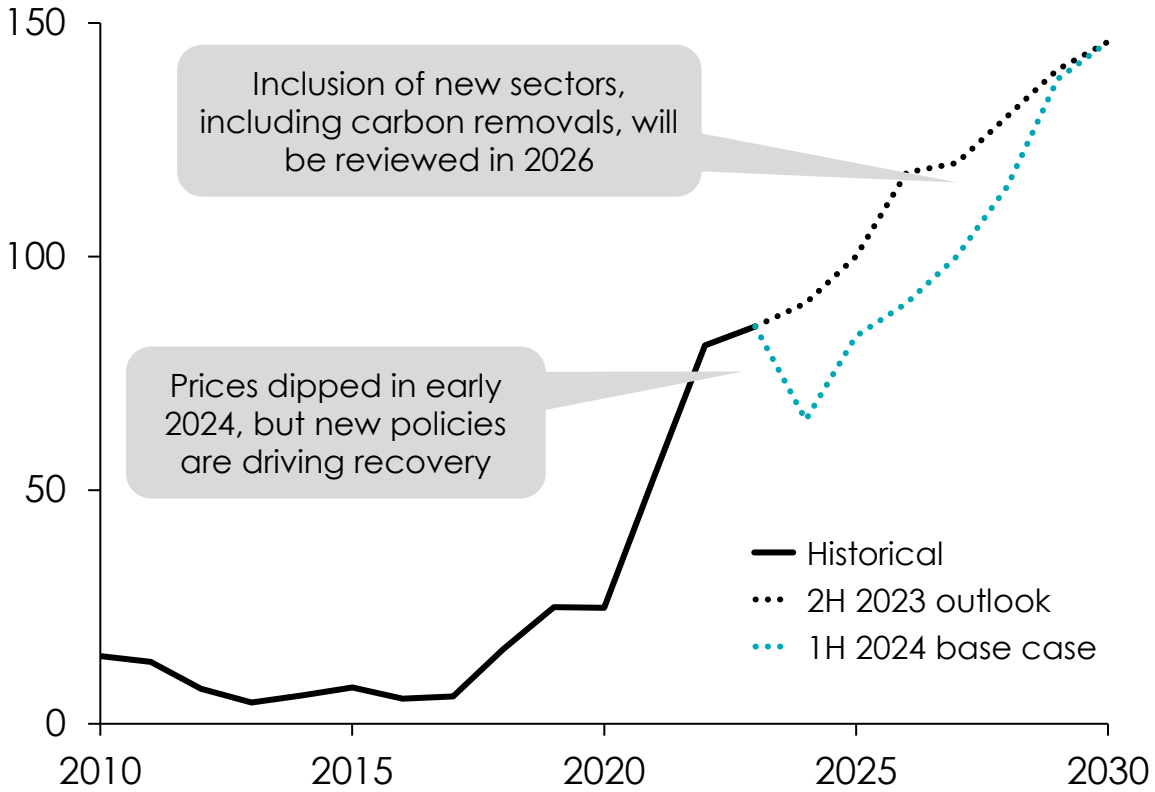


Source: European Commission, EEA (2023), Transport and Environment (2024) State of European Transport 2024

Despite fluctuating carbon prices, EU ETS remains a strong market lever

Historical and forecast price of EU emission allowances

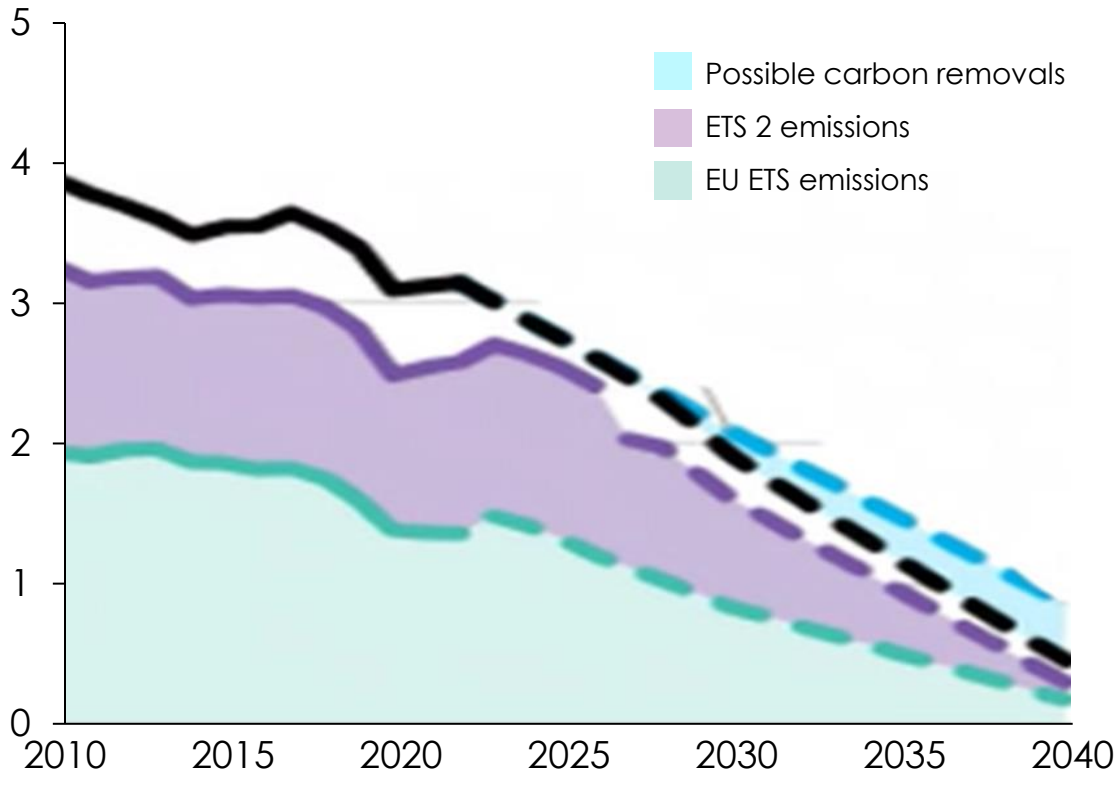
EUR/metric ton, nominal



Carbon price could reach 200EUR/t around 2035

EU ETS emissions caps and possible 2040 target

Billion metric tons of CO2e



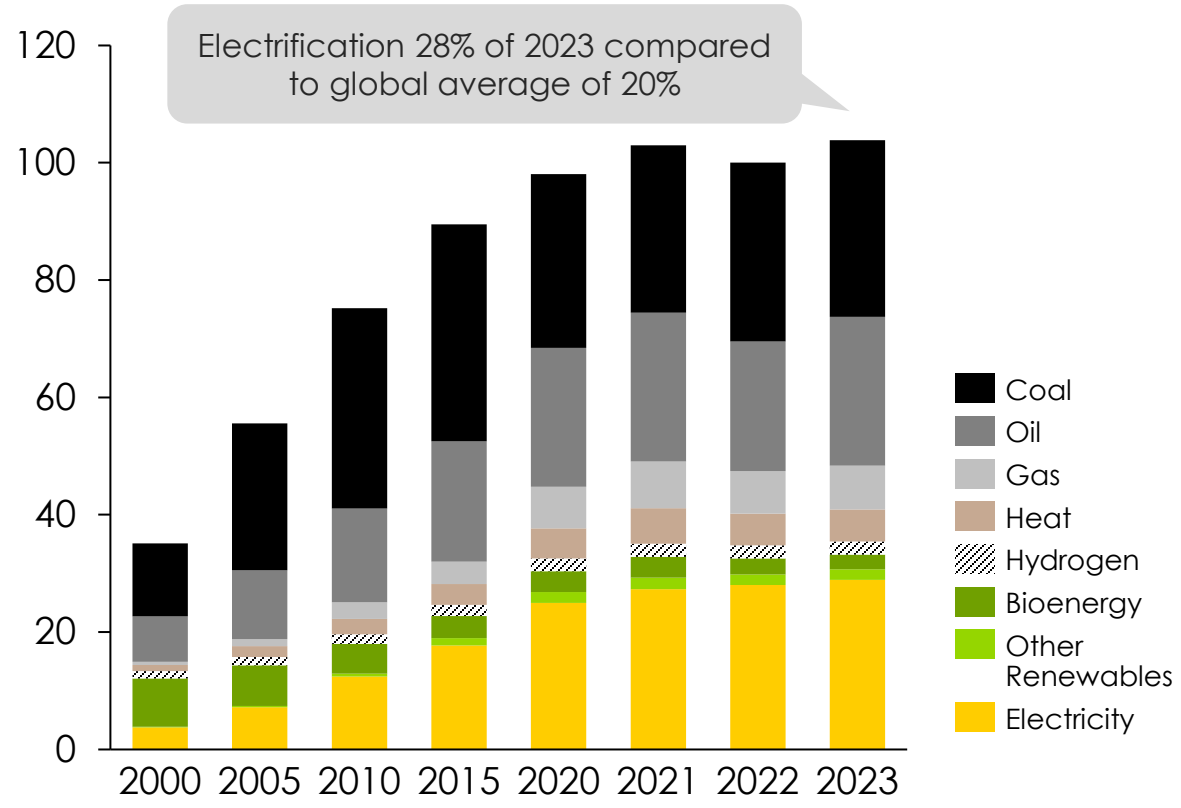
EU ETS goes to zero by 2040

Note: sectors included in ETS are power generation and industrial plants (e.g., cement, steel, refineries); ETS2 includes buildings, road transport and other smaller industries not previously covered by ETS (e.g., ceramics, pulp & paper);
Source: BNEF; Trading Economics (2023) EU Natural Gas; ICE Endex (2023) Dutch TTF Natural Gas Futures (accessed 06/02/24); BNEF (2023), 2H 2023 LCOE Update

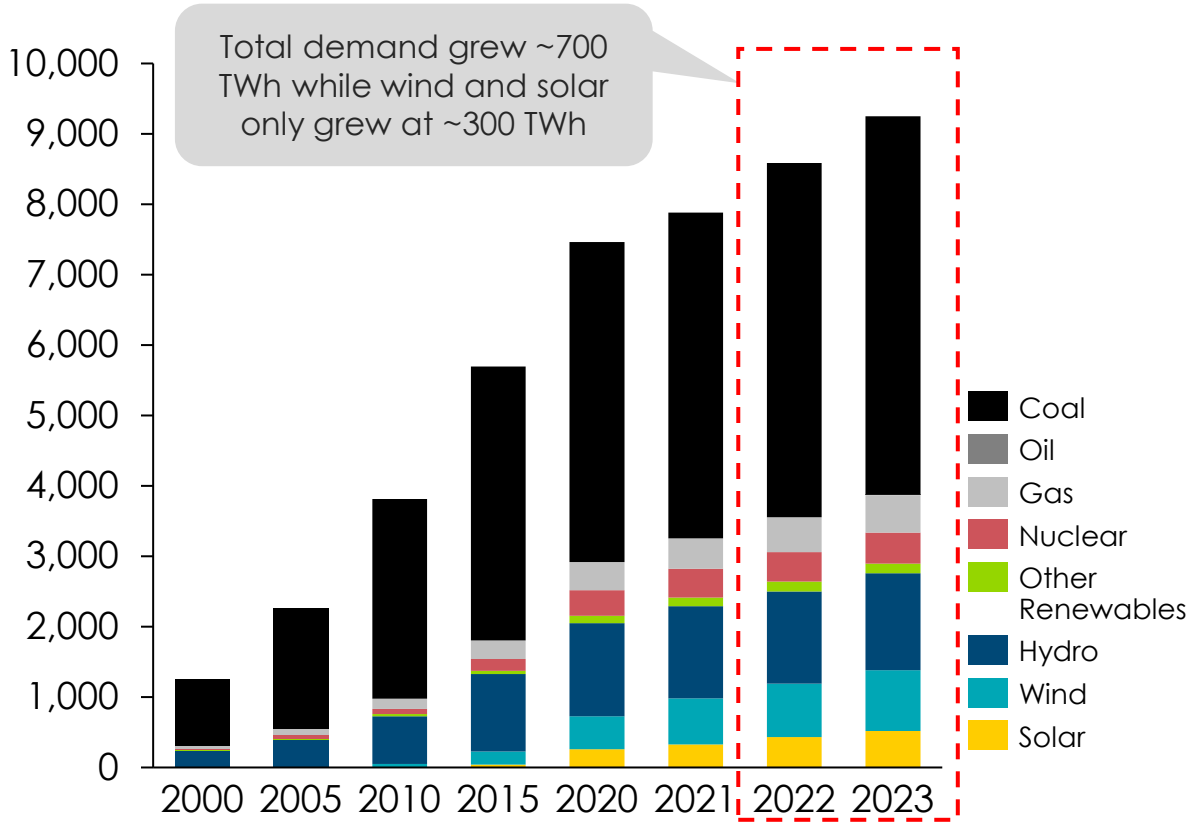
China

Growing electricity demand has outpaced renewable generation, meaning coal generation continues to grow

Final Energy Demand by Fuel (PJ)



Power generation by technology (TWh)



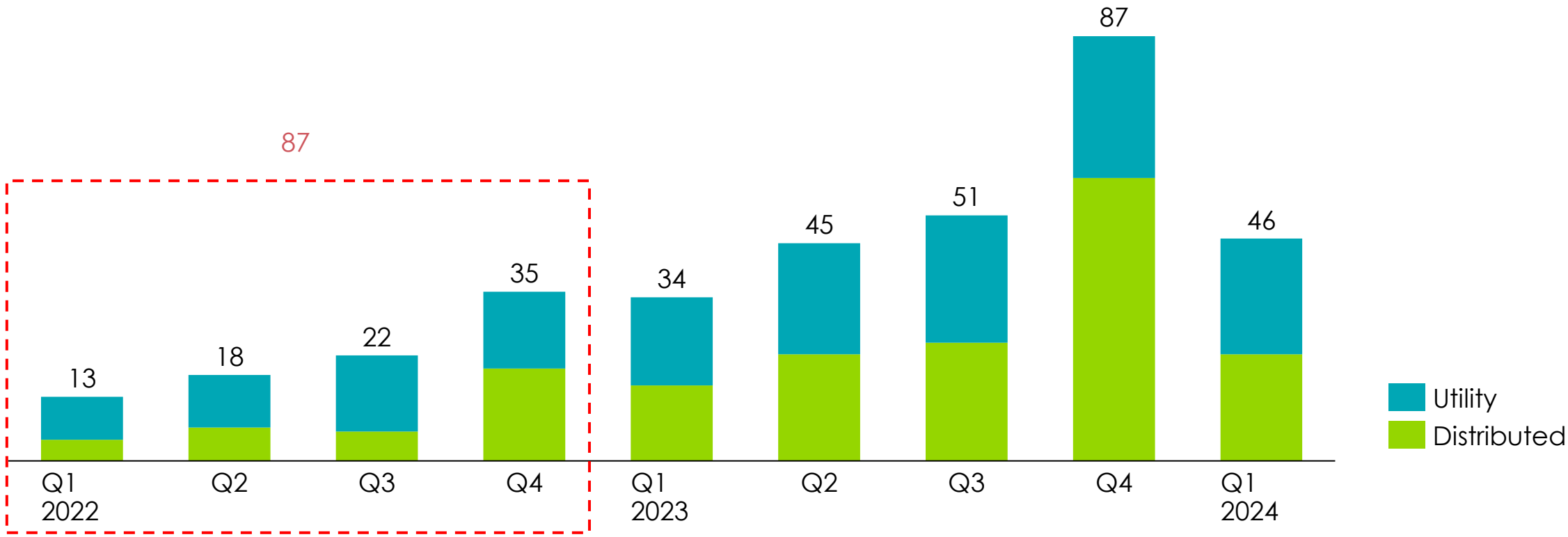
Given outlook for hydro generation, the maintained rate of renewables installation means that power emissions could have already peak

Source: BNEF World Energy Outlook 2023

Amount of solar capacity installed in Q4 of 2023 equal to amount of solar capacity installed in all of 2022

Solar capacity

GW installed per quarter

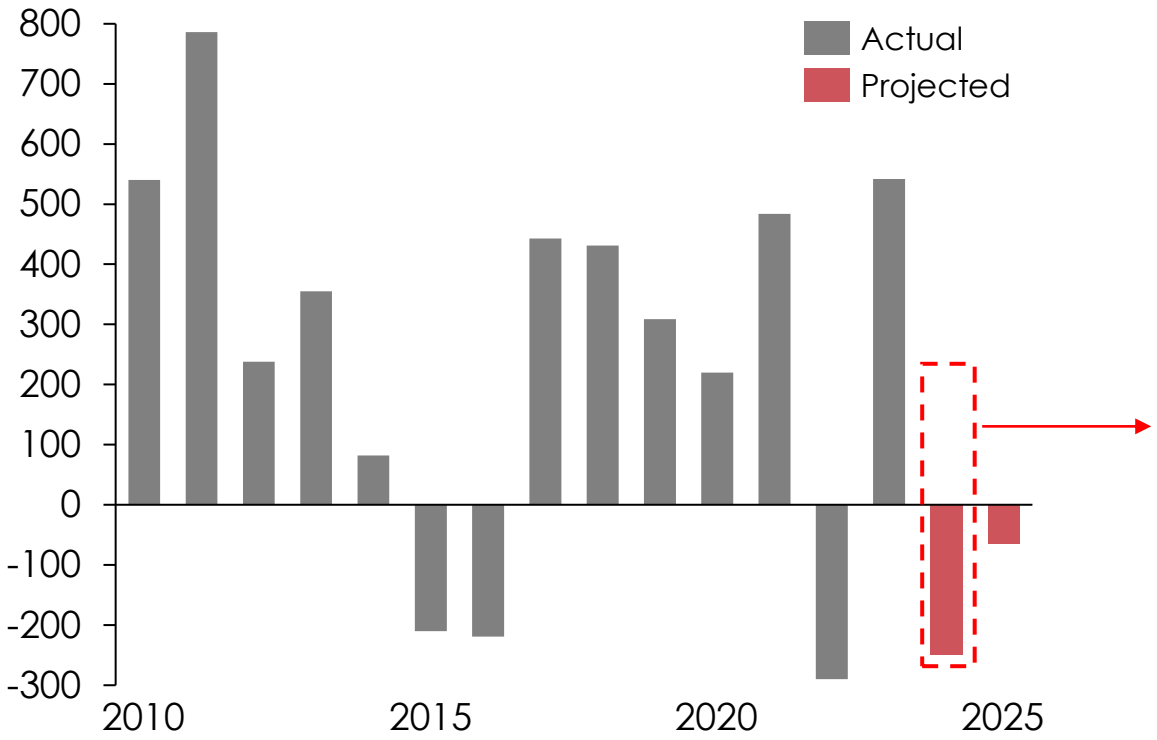


Source: Atlantic Council

Emissions from fossil fuels and cement may actually have peaked in 2023, with year-over-year emissions already dropping in March 2024

Annual change in emissions from fossil fuels & cement

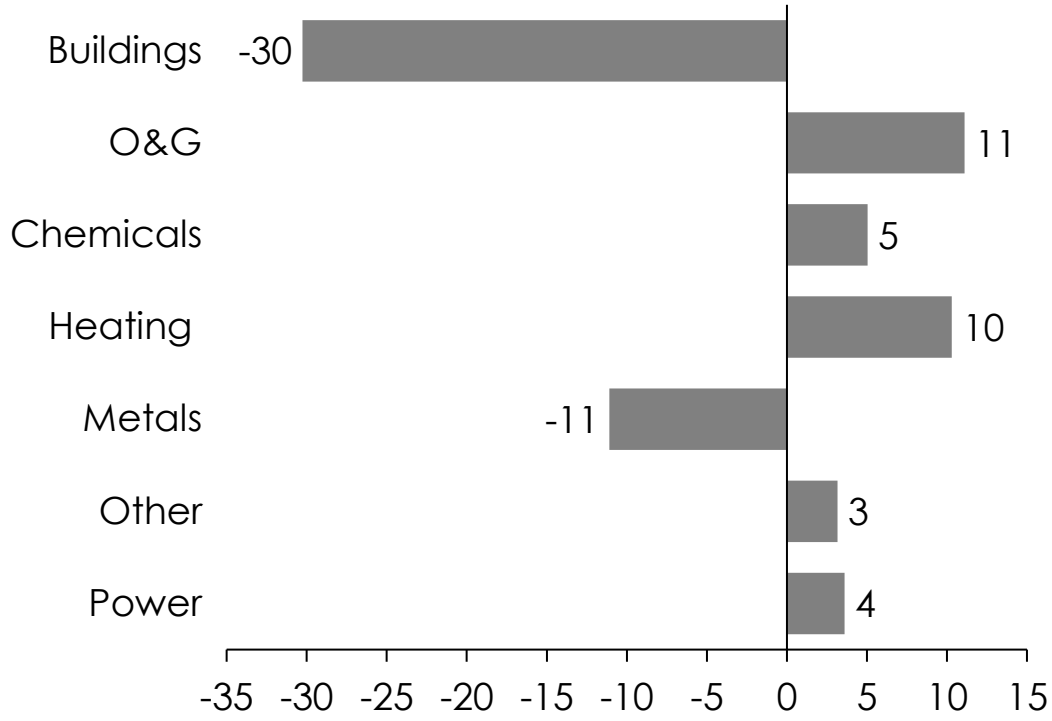
MtCO2



Q4 2023 predicted emissions to enter structural decline beginning 2024

Actual year-over-year change in emissions in March 2024

$MtCO_2$, by sector and fuel



Actual drop driven by clean energy growth and construction-industry contraction

Source: Carbon Brief

Investments being made in grid transmission and storage

Overview of UHV lines and energy generation, 2019

Recent headlines on China's grid investments

China Daily

State Grid to pump 500b yuan into power system

State Grid Corp of China said it would invest more than 500 billion yuan ($69.6 billion) in grid network construction this year to ensure...

17 Jan 2024

Electrek

China's first large-scale sodium-ion battery charges to 90% in 12 minutes

The Fulin Sodium-ion Battery Energy Storage Station entered operation on May 11 in Nanning, the capital of the Guangxi Zhuang autonomous region...

3 weeks ago

Global Times

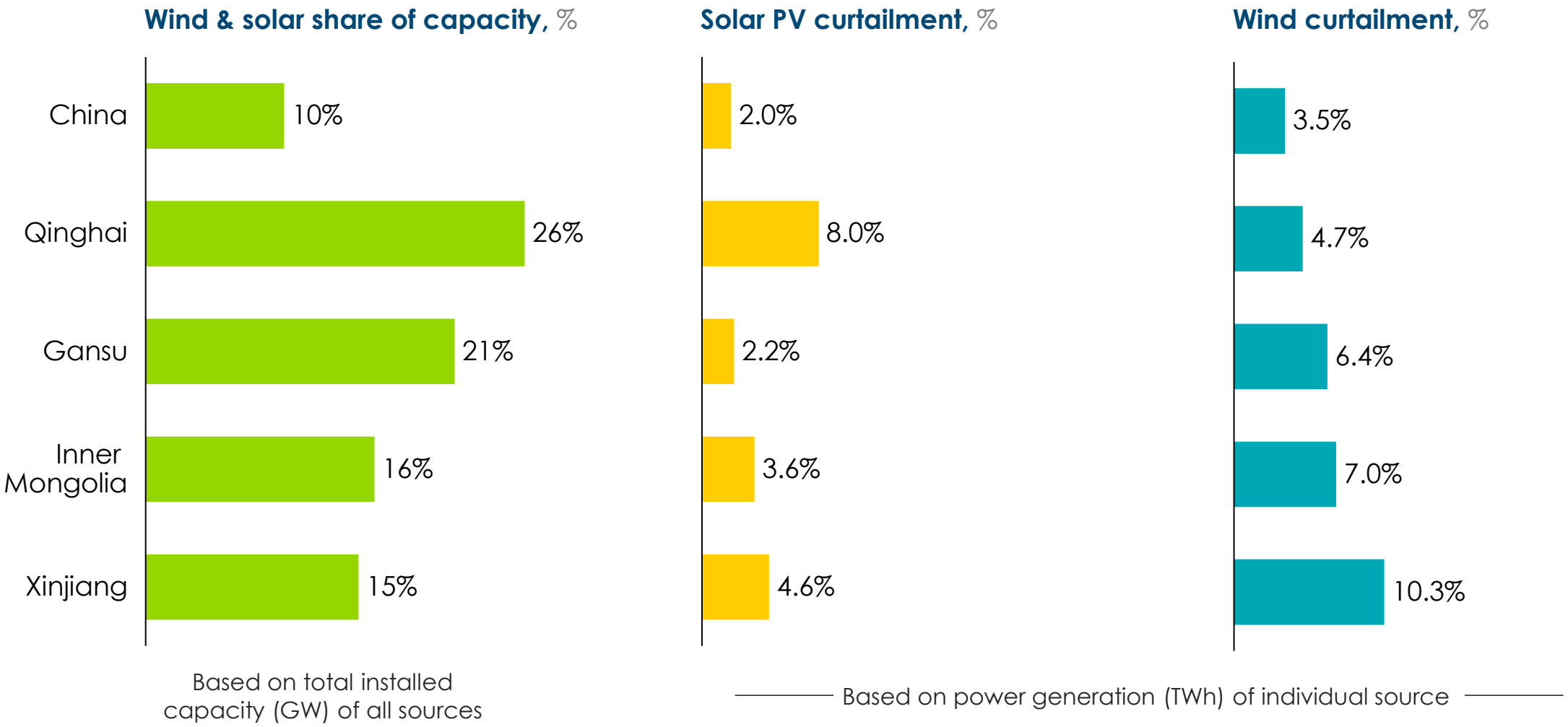
2.1 million kilowatts! Construction of world's highest-altitude pumped-storage power station kicks off in SW China's ...

Construction of the world's highest-altitude pumped-storage power station kicks off Thursday in Southwest China's Sichuan Province.

12 Jan 2024

Illustration: Erik Vrielink "China's UHV Grid" (Fairley, 2019)
Source: Google search results

China's power market currently lacks effective mechanisms for interprovincial trading, resulting in curtailed renewable generation

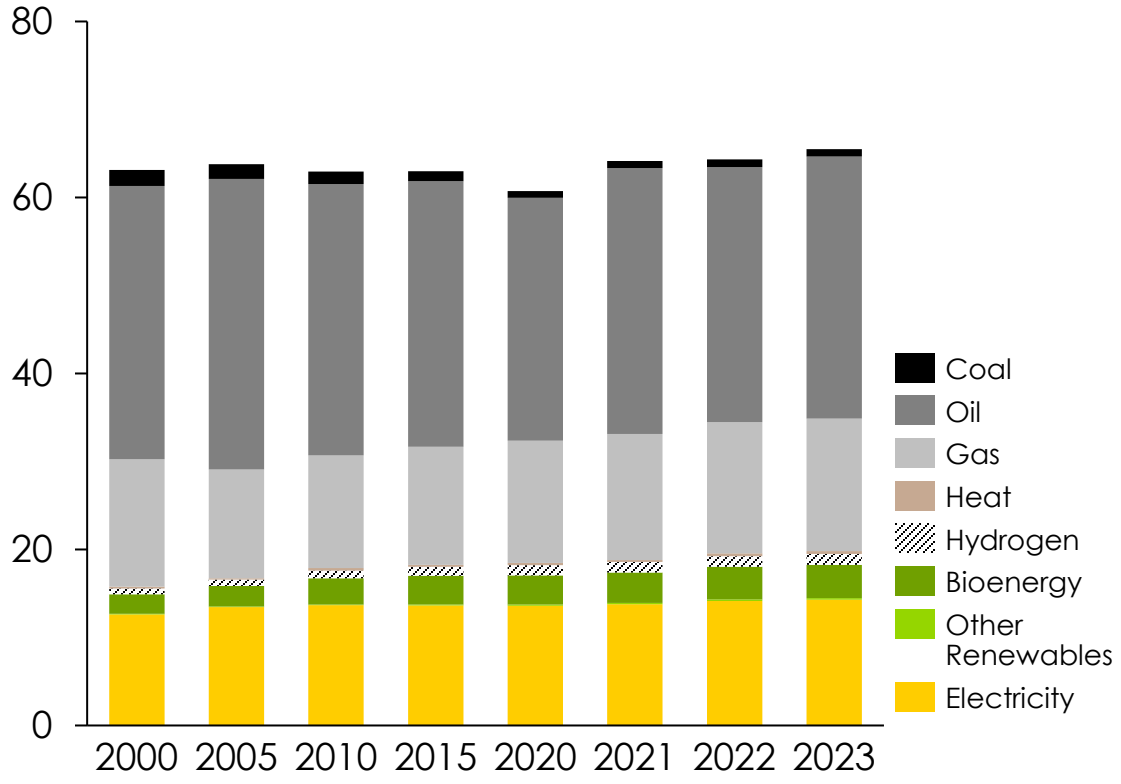


Source: Energy Post EU "China can learn from the EU about power market design and infrastructure build-out"

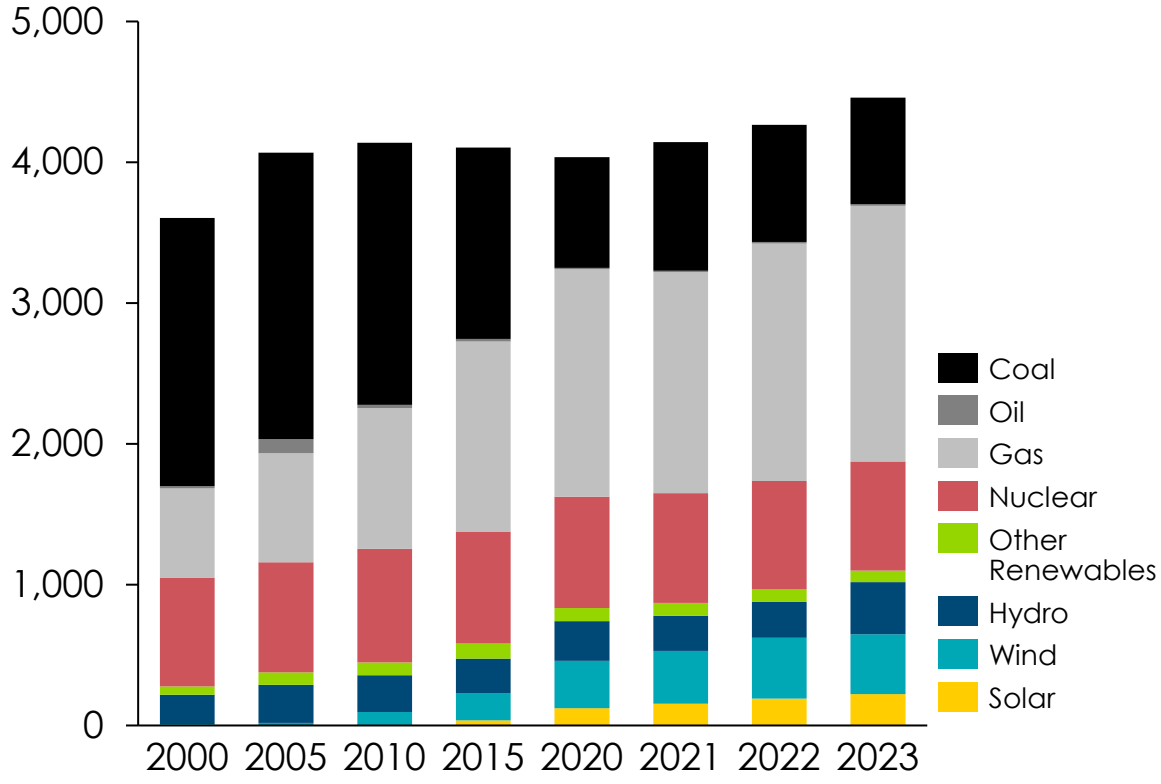
US

While electricity share of Final Demand holding steady, renewables share of generation continues to increase

Final Energy Demand by Fuel (PJ)



Power generation by technology (TWh)

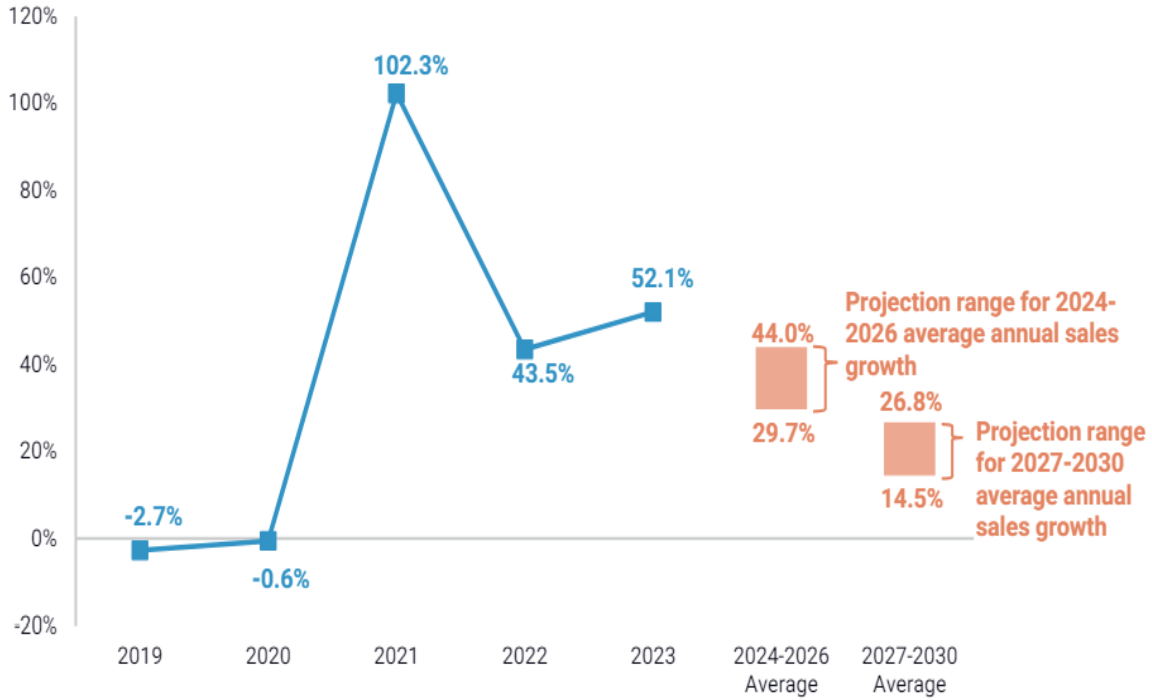


Source: BNEF World Energy Outlook 2023

Since the passing of the IRA, progress in electric vehicles and clean electricity deployment is mixed

Annual growth rate in electric vehicle sales

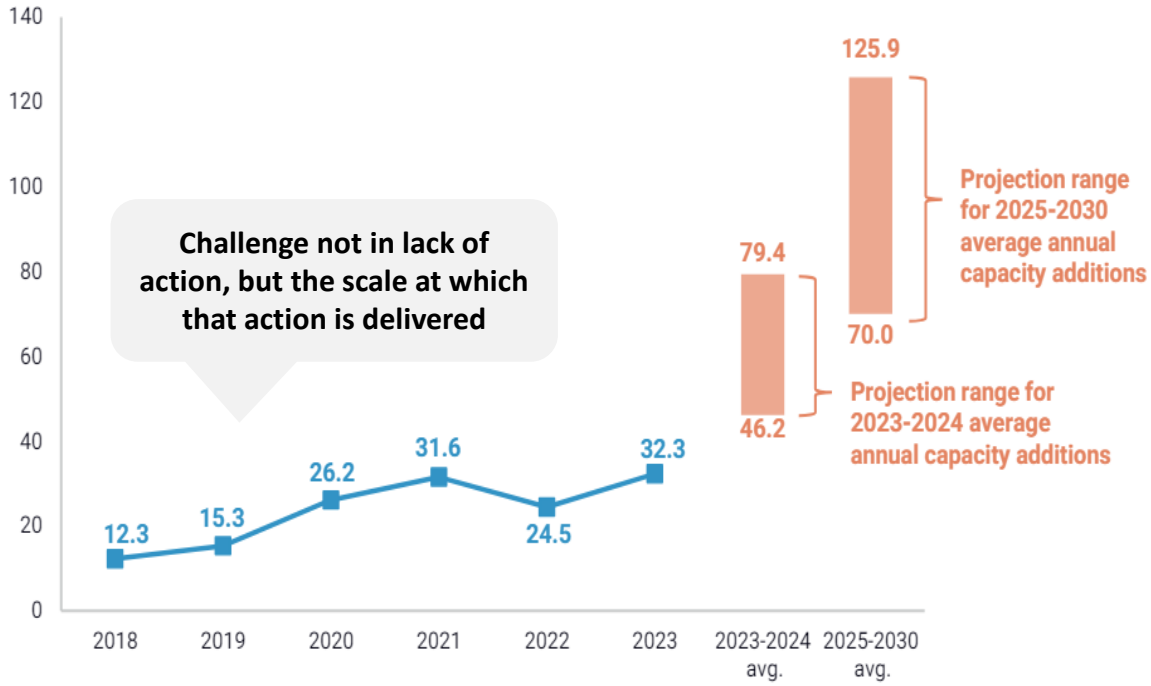
% increase year-over-year



EV deployment can remain on a track consistent with the IRA's 40% emissions reduction objective, even if annual sales growth slows in 2024, provided it stays in the 30-40% range.

Annual clean electricity capacity additions v projections

GW



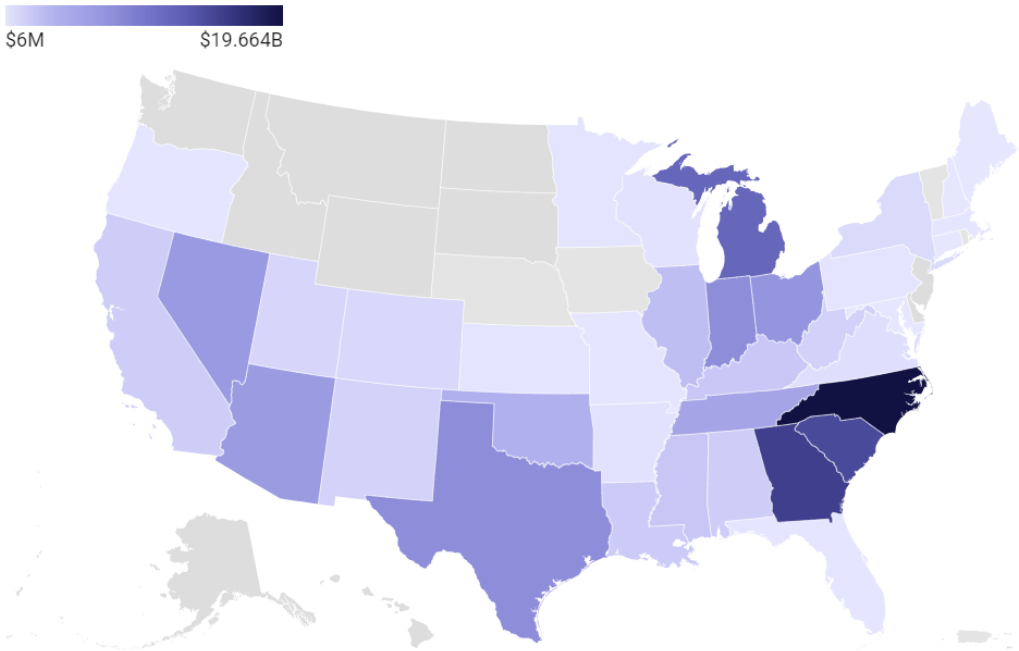
Even though investment in utility-scale clean electricity generation and storage capacity reached record levels in 2023, it is at risk of falling behind post-IRA projections.

Source: Rhodium Group Clean Investment in 2023: Assessing Progress in Electricity and Transport (Feb 2024)

Real impact seen through projects, jobs, and investments across clean energy related sectors

Sector	Projects	Investments	Jobs
EV	137	$77.6B	57.6K
Battery/Storage	51	$21....	15.2K
Solar	73	$14B	25.6K
Hydrogen	17	$6.1B	2.9
Wind	19	$2.9B	1.8K
Grid, Transmission and Electrification	16	$1.8B	2.3K
Energy Efficiency	133	$6M	200
Biofuel	1	N/A	40
Geothermal	1	N/A	N/A

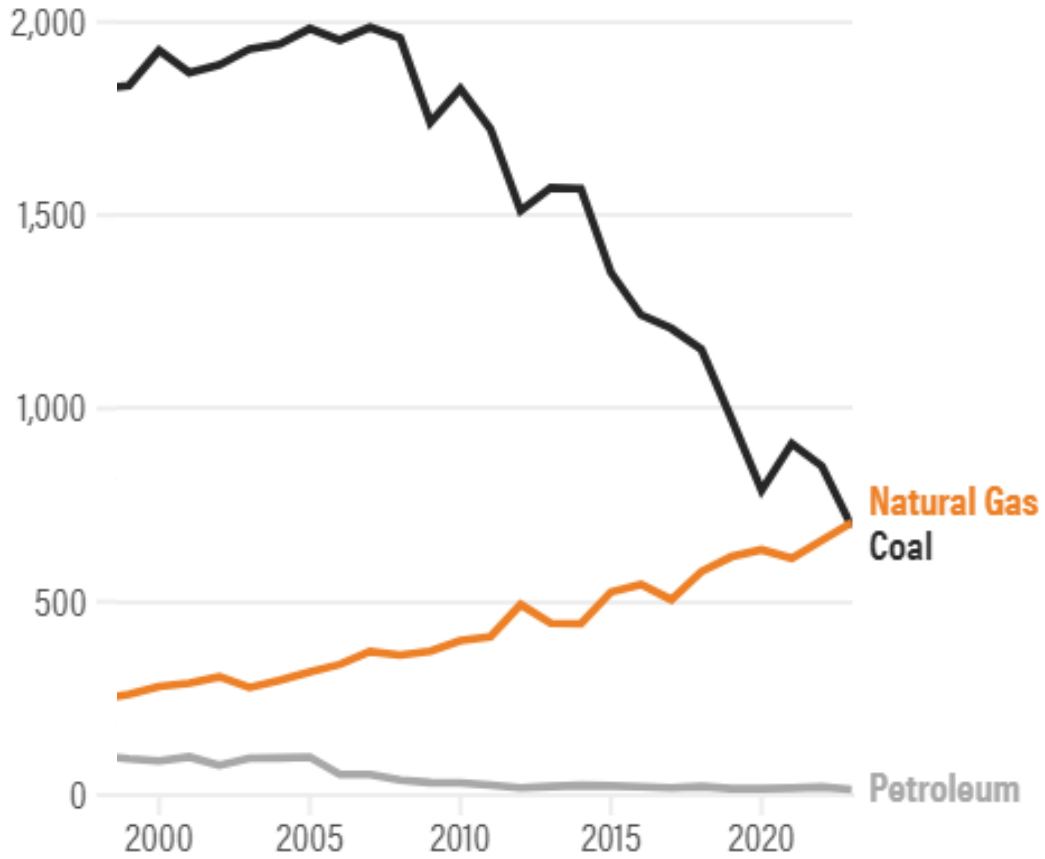
Project, investment, and job creation per state
August 2022 to present



Source: Manufacturing Dive; E2

New EPA regulations strict for coal plants but do not address the largest source of current carbon pollution in the power sector, natural gas

Power Sector Emissions by Major Source, $MTCO_2$

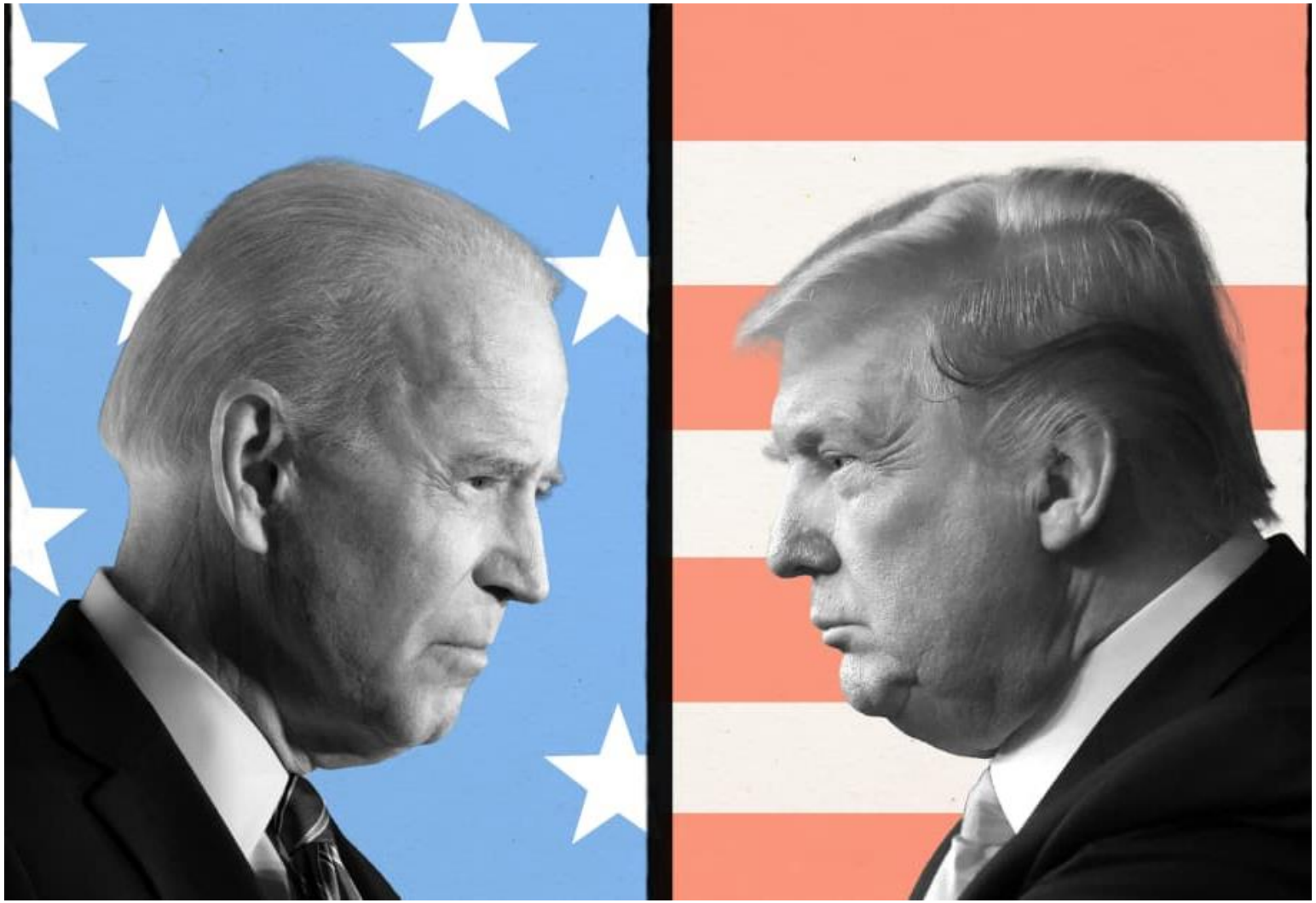


Type of coal plant	EPA Rule, April 2024
Long-lived plants (operating beyond 2039)	Reductions equivalent to 90% carbon capture and storage by 2032
Medium-term retirement (retiring between 2032 and 2039)	Reductions equivalent to 40% gas co-firing by 2030
Near-term retirement (retiring before 2032)	Reporting requirement only

Type of gas plant	EPA Rule, April 2024
Peaker/Low Load (operates < 20% of hours in a year)	Emissions based on using lower emitting fuels (e.g., natural gas rather than diesel)
Intermediate (operates 20%-40% of hours in a year)	Emissions based on efficient simple cycle plant operation (~1,150 lbs. CO2/MWh)
Baseload (operates > 40% of hours in a year)	Reductions equivalent to 90% CCS by 2032

Source: World Resource Institute "4 Things to Know About US EPA's New Power Plant Rules" (2024)

What could the future hold?



Biden

- Consolidate and expand federal legislation (IRA)
- Full force on permitting and build-out

Trump

- Rebrand IRA
- Manufacturing jobs remain
- Executive actions could disrupt other areas (e.g., EVs and renewables)

Energy Pathways USA

- **Publications**
  - Supply chains (August 2023)
  - Future investments in clean energy (December 2023)
  - Upcoming report on load growth (Q3 2024)

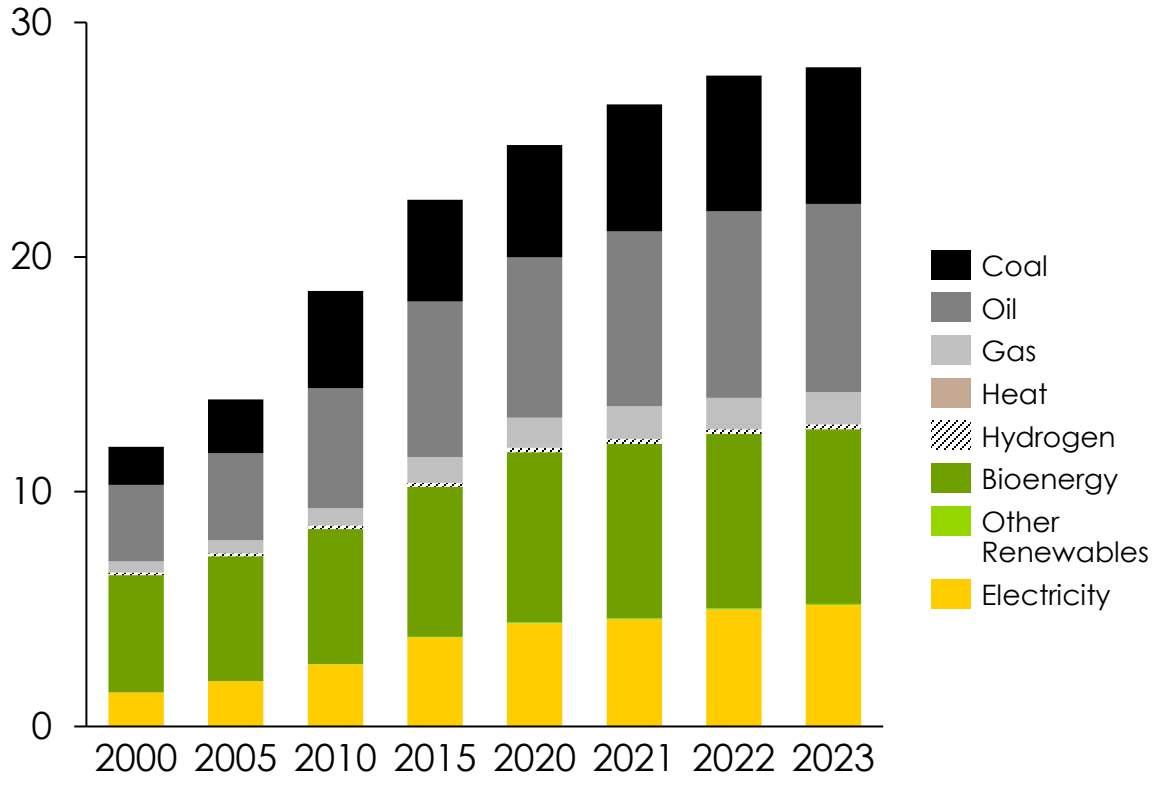
- **Private roundtables**
  - Integrated Energy Systems as Drivers of Decarbonization (April)
  - Future Pathways for Hydrogen Development and Demand (July 11)

- **Other**
  - Interpretation of new GHG emissions guidelines from power
  - Ongoing webinars

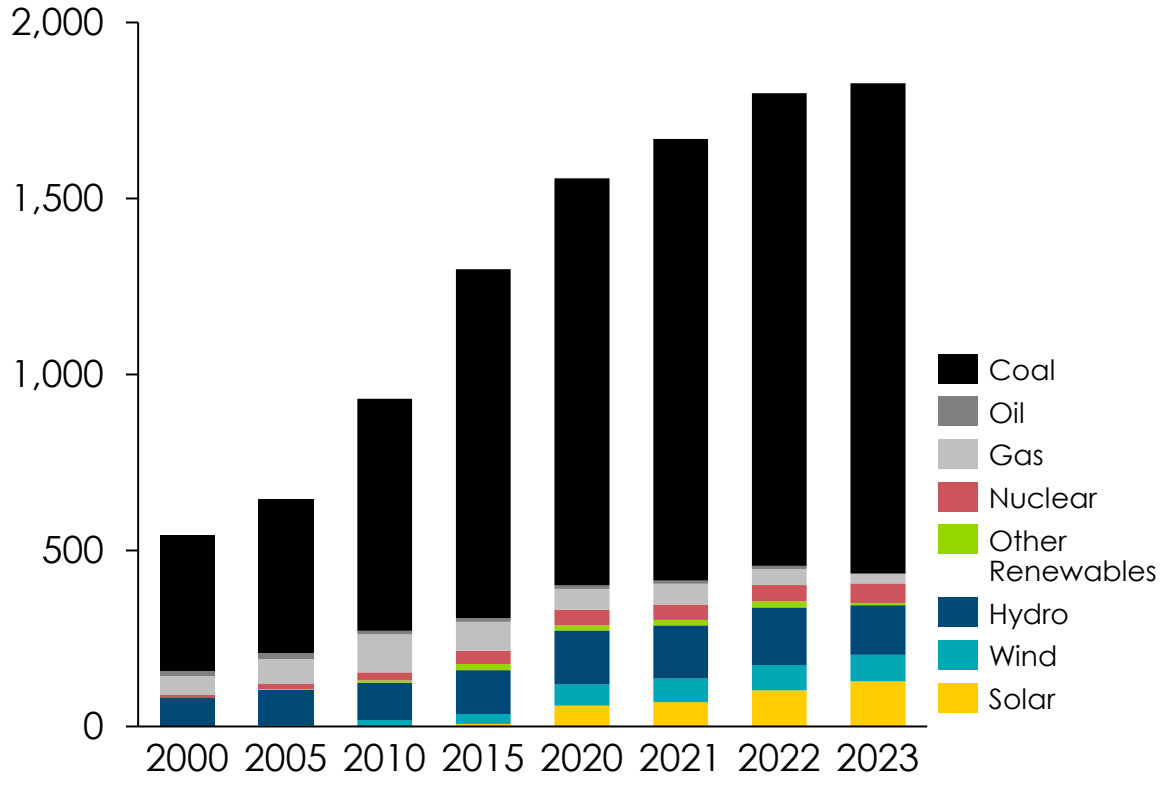
India

Electricity demand continues to grow, resulting in more coal generation

Final Energy Demand by Fuel (EJ)



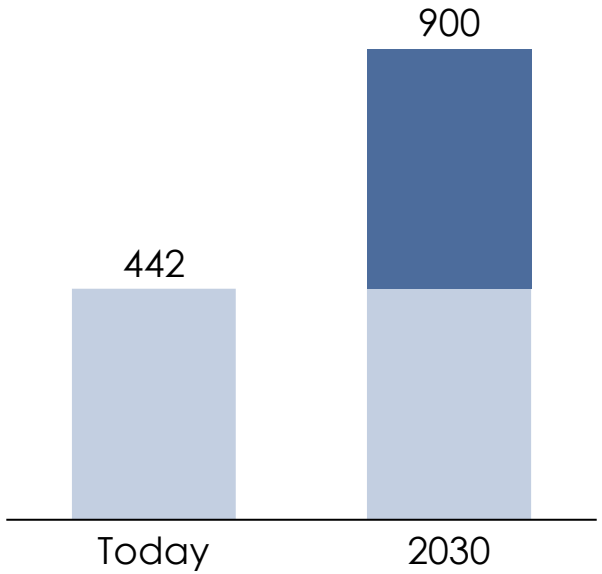
Power generation by technology (TWh)



Source: BNEF World Energy Outlook 2023

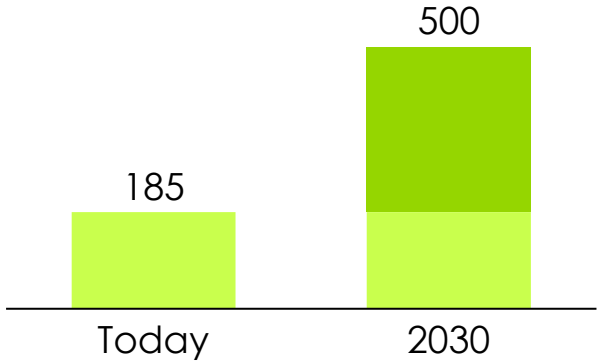
With power demand expected to continue rising faster than new renewable supply, question if coal can start phasing out before 2030

Power capacity, GW



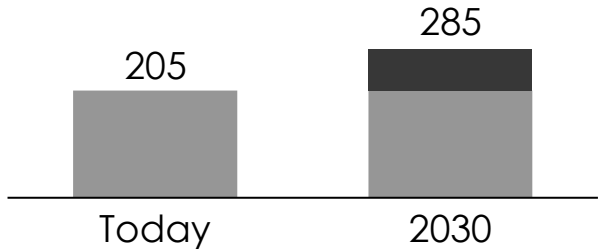
Total

Government aims to deploy 50GW per year of renewables starting in 2024



Renewables

Government has announced 80GW of new coal to be added by 2030



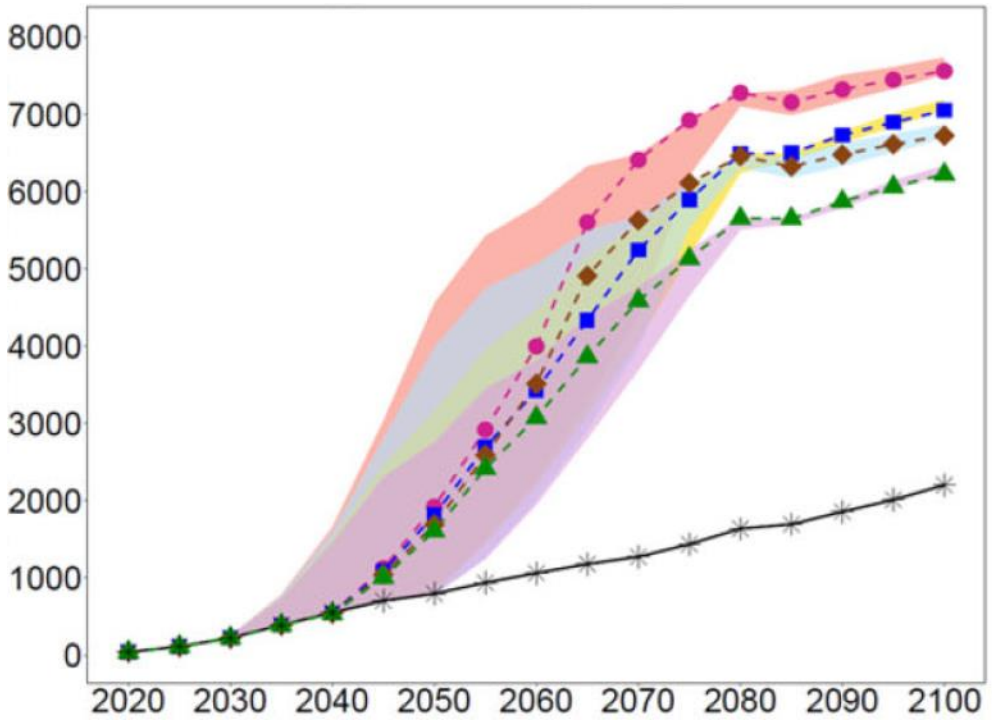
Coal

Annual growth, TWh/year

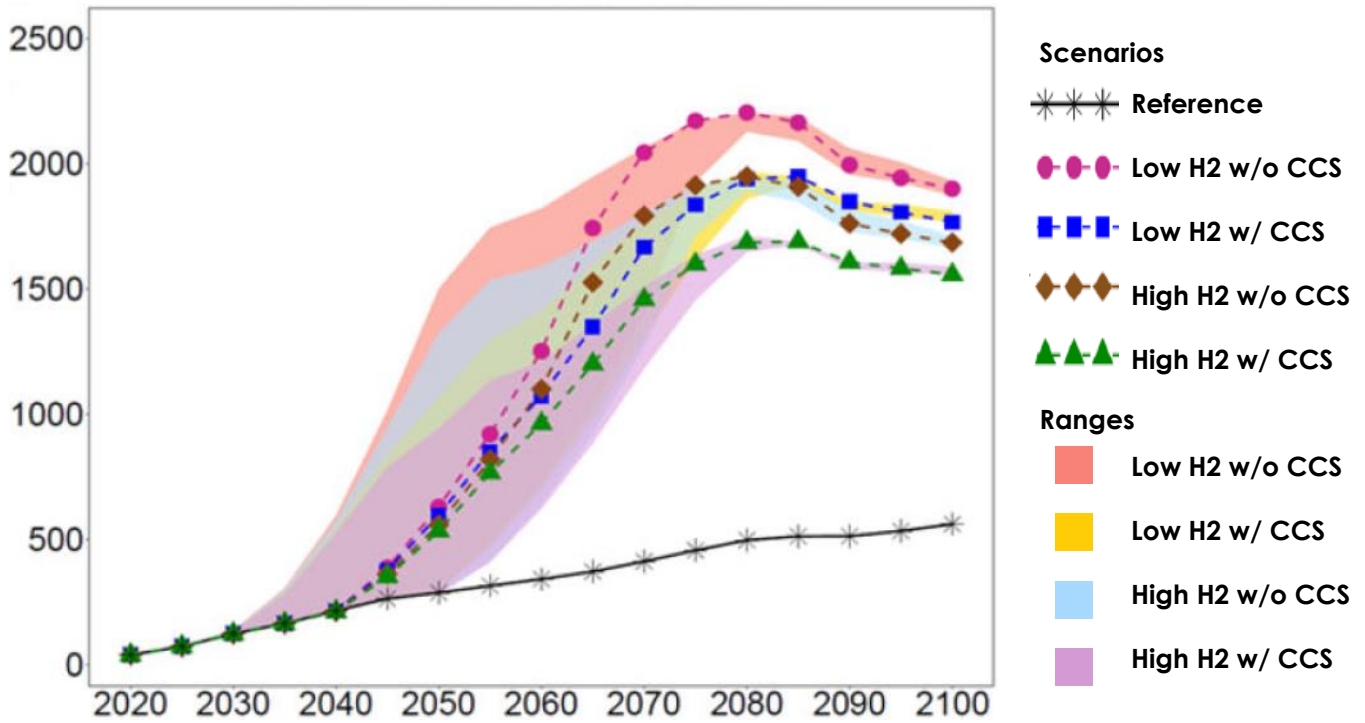
Note: Government expects to deploy 50GW RE per year by 2024
Source: CEEW, Reuters, NTPC

While local organizations see massive potential for solar and wind, massive deployment of technologies not expected to take off until after 2040

Total generation capacity of solar, GW



Total generation capacity of Wind, GW



Impediments to deployment

- Policy framework and auctions
- Discom reform
- Supply of finance
- Cost effective storage solutions
- Supply chains for solar and batteries
- Shift of coal fleet to flexible operation

Source: CEEW "Implications of a net-zero target for India's sectoral energy transitions and climate policy" (Oxford Open Climate Change, 2022)

Renewable Energy Round-the-Clock (RTC) contracts could enable faster deployment

Round-the-Clock (RTC)

Power generators to supply a specified quantity of electricity at specified times throughout the year

Renewable Energy RTCs

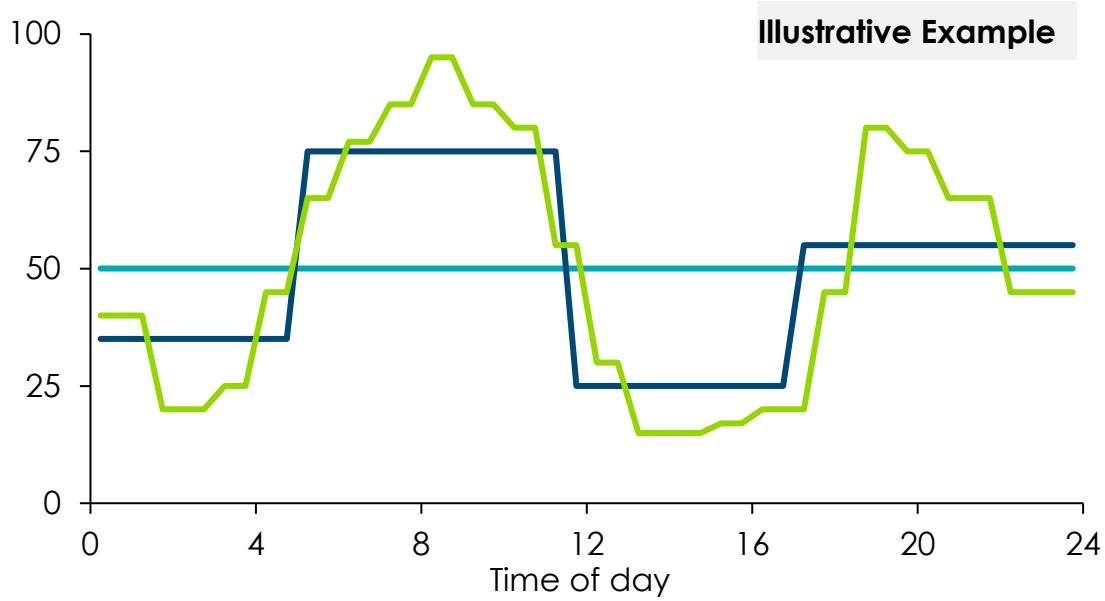
Renewable RTCs must include storage to ensure power still supplied when natural resources aren't producing

↳ **Easier to integrate variable renewables into grid:** a firm power supply removes balancing issues for grid operators

In addition to specifying times and quantity of power supplied, renewable RTCs include Capacity Use Factors (CUFs) which refer to the share of power that needs to come from renewables over specified time periods

↳ **Actual installed capacity grows even faster:** renewable RTC projects must be oversized by 3-4x to comply with CUF specifications

RTC Power Supply to Grid, GW

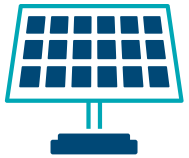


RTCs vary in their **time blocks**

- **Fixed supply** is constant regardless of demand, with time blocks on an annual basis
- **Slot-wise supply** steps up/down with peak demand hours, time slots can range from weeks to hours
- **Real-time supply** adjusts to demand, with blocks as short as 15-minutes

Rooftop solar scheme for lower- and middle-income households

10 million households



20-25 GW capacity

10-year payback

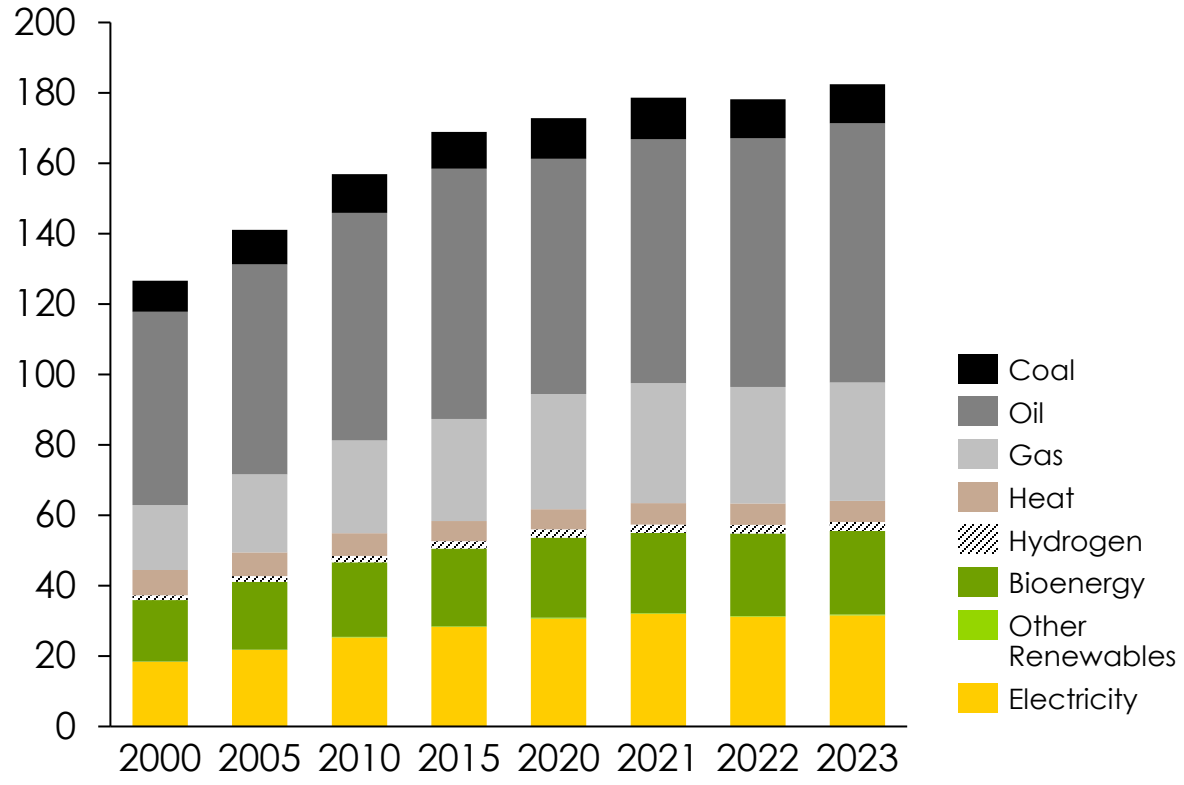
Electricity use (TWh/month)	Capacity (kW)	Financial subsidies	
		(IDR)	(USD)
Under 150	1-2	30,000 – 60,000	~360-720
150-300	2-3	60,000 – 78,000	~720-930
Above 300	Above 3	78,000	~930

Source: https://cleartax.in/s/rooftop-solar-scheme

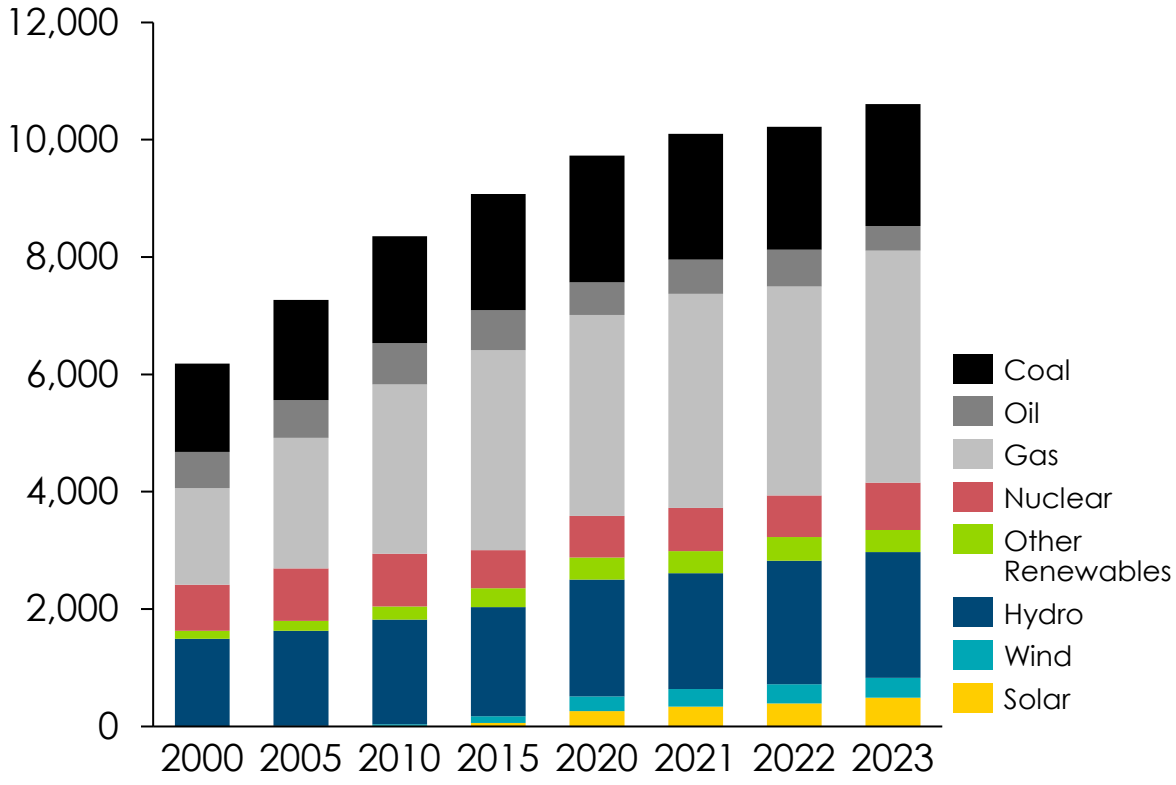
Rest of World

Electrification rates growing but seeing an increase in gas generation as well as renewables

Final Energy Demand by Fuel (EJ)



Installed capacity by technology (GW)

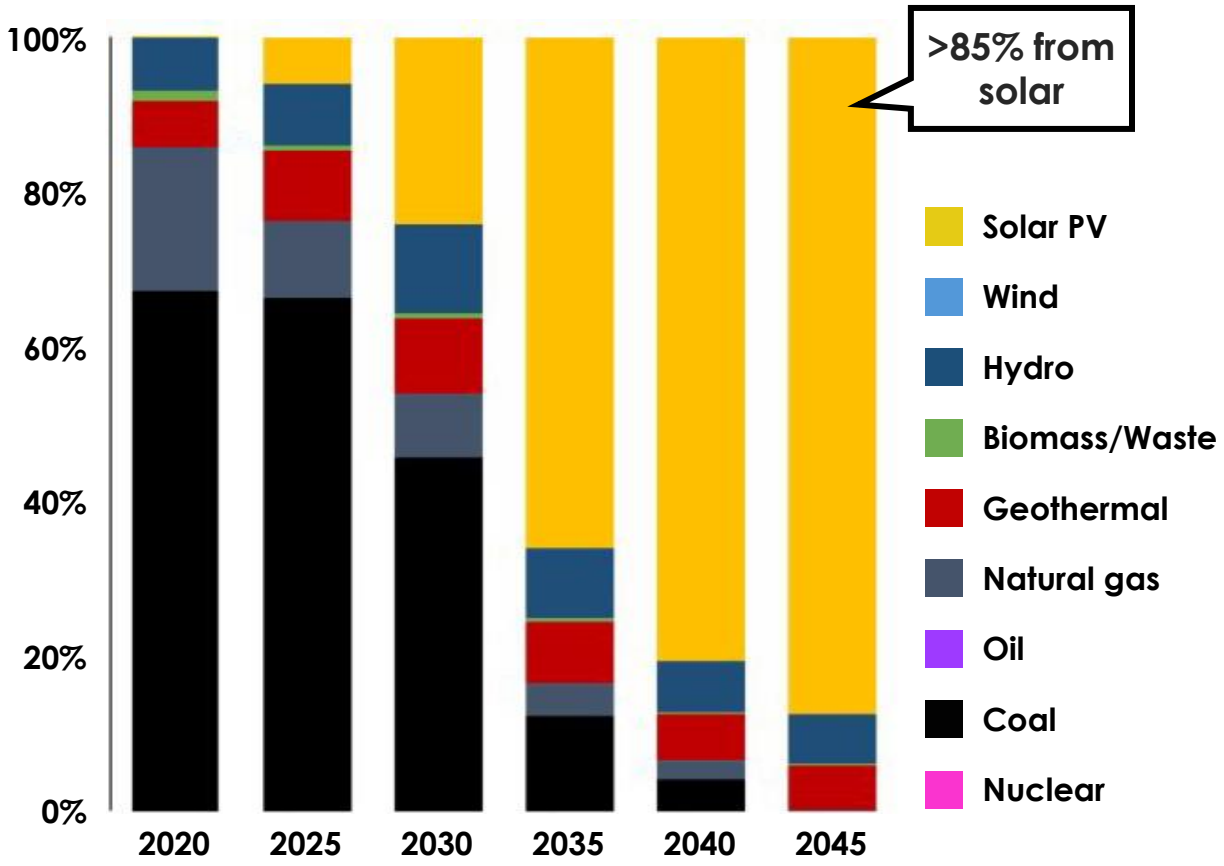


Source: BNEF World Energy Outlook 2023

Although Indonesia could radically decarbonize power system with solar, existing targets for 2030 are relatively unambitious

Indonesia power system, electricity generation

Generation share by fuel (%)



Climate targets and CAT review

Overall rating
CRITICALLY INSUFFICIENT

Policies and action	Conditional NDC target
against fair share **CRITICALLY INSUFFICIENT** 4°C+ WORLD	against modelled domestic pathways **CRITICALLY INSUFFICIENT** 4°C+ WORLD
Unconditional NDC target against fair share **CRITICALLY INSUFFICIENT** 4°C+ WORLD	**Climate finance** **NOT APPLICABLE**

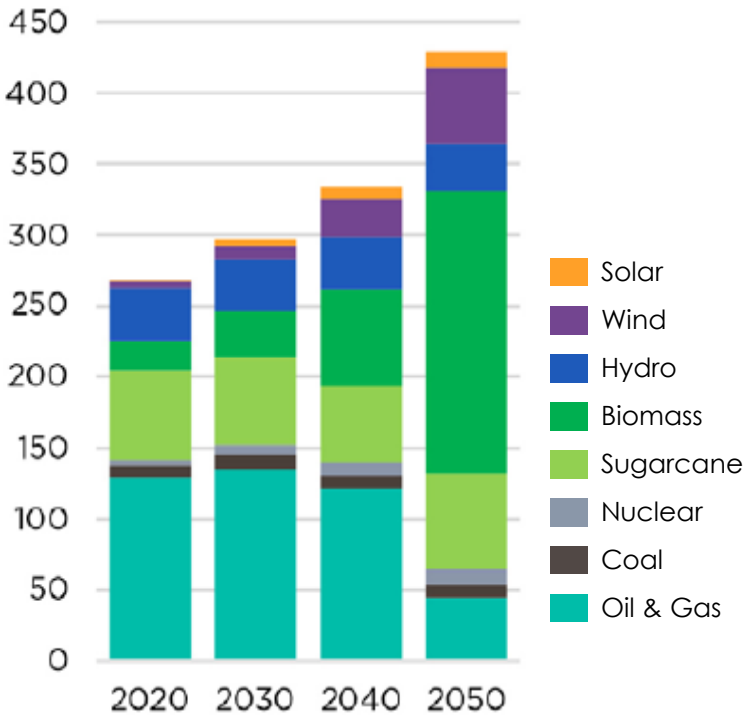
Net zero target	year **2060**	comprehensiveness not rated as **INFORMATION INCOMPLETE**

Land use & forestry	historically considered a **SOURCE**

Brazil's net zero pathways heavily depend on biofuels while disregarding the high potential for electrification using wind and solar

Primary energy consumption in Net Zero

Mtoe



Alternative technical route, restrictions around water and CCS availability; carbon budget of 24.9 $GtCO_2$

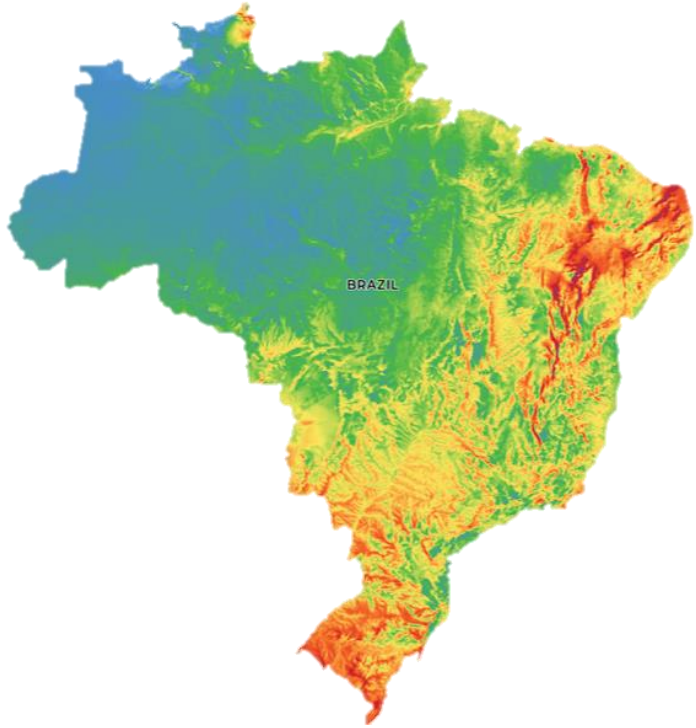
Solar power potential

kWh/m^2

Long term average of DNI (1999-2018), yearly totals MWh/m^2

Wind speed (at 100 m height)

m/s



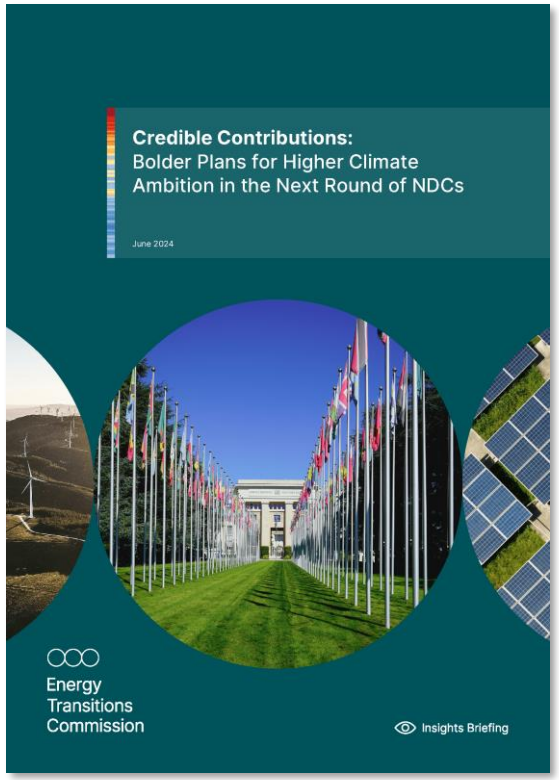
Mean wind speed at 100 m height, m/s

Note: passenger road transportation includes urban busses, light commercial vehicles, and 2-/3-wheelers

Source: CEBRI "Carbon Neutrality 2050" (2023); Projeto Decarboost "Uma Estratégia de Descarbonização para uma Economia Brasileira de Zero Carbono Líquido em 2050" (2023)

NDCs

NDCs 3.0: next round of Nationally Determined Contributions due at COP30



- **Governments can and must raise ambition** in the next round of Nationally Determined Contributions - the so-called "NDCs 3.0" due at COP30 in Brazil - if we are to limit the impact of climate change.
- Success in the low-carbon transition to date has been driven by **industry's response to ambitious government targets** - accelerating deployment and driving down costs. Industry recognises the opportunity in the next round of NDCs and calls on governments to prioritise delivering high-ambition NDCs which will provide certainty, unlock investment and accelerate technology deployment.
- In turn **industry can help government be confident** that progress towards a net-zero economy is both technically and economically possible – the technology is in place, commitments are being made, and the focus must now be on deployment

2 approaches to determining NDCs

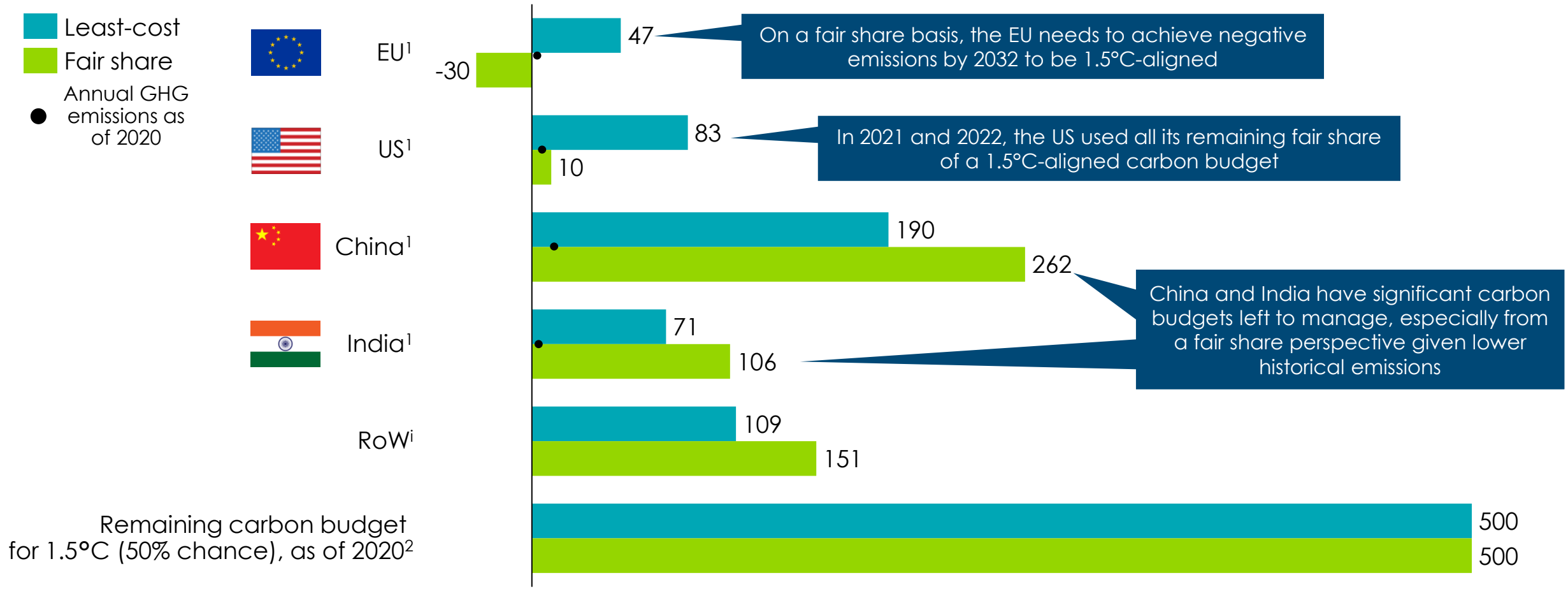
"Least-cost approach" estimates the transition pathways for different countries which would result in global least cost reduction, given the differing potential for different countries to reduce emissions.

"Fair share approach" considers a range of academic study results that offer different viewpoints of what could be fair, including considerations on historical responsibility, capability, equality and cost effectiveness

Climate Action Tracker carbon budget estimates per country show historical emissions of developed countries leave little margin for excess by 2050

1.5°C-aligned 2020-2050 carbon budgets per country based on CAT least-cost and fair share modelling approaches

$GtCO_2e$



Notes: [i] RoW – Rest of the World; value was estimated by subtracting sum of values for the EU, the US, China and India from the global carbon budget estimate
Source: Systemiq analysis for the ETC based on [1] Climate Action Tracker (2023), Country assessment for the EU, the US, China and India [2] IPCC (2021), *Climate Change 2021: The Physical Science Basis,* Working Group I contribution to the IPCC Sixth Assessment Report (AR6)

Country-level assessments suggest current NDCs are broadly not aligned with what an ideal NDC should look like, except for LDCs

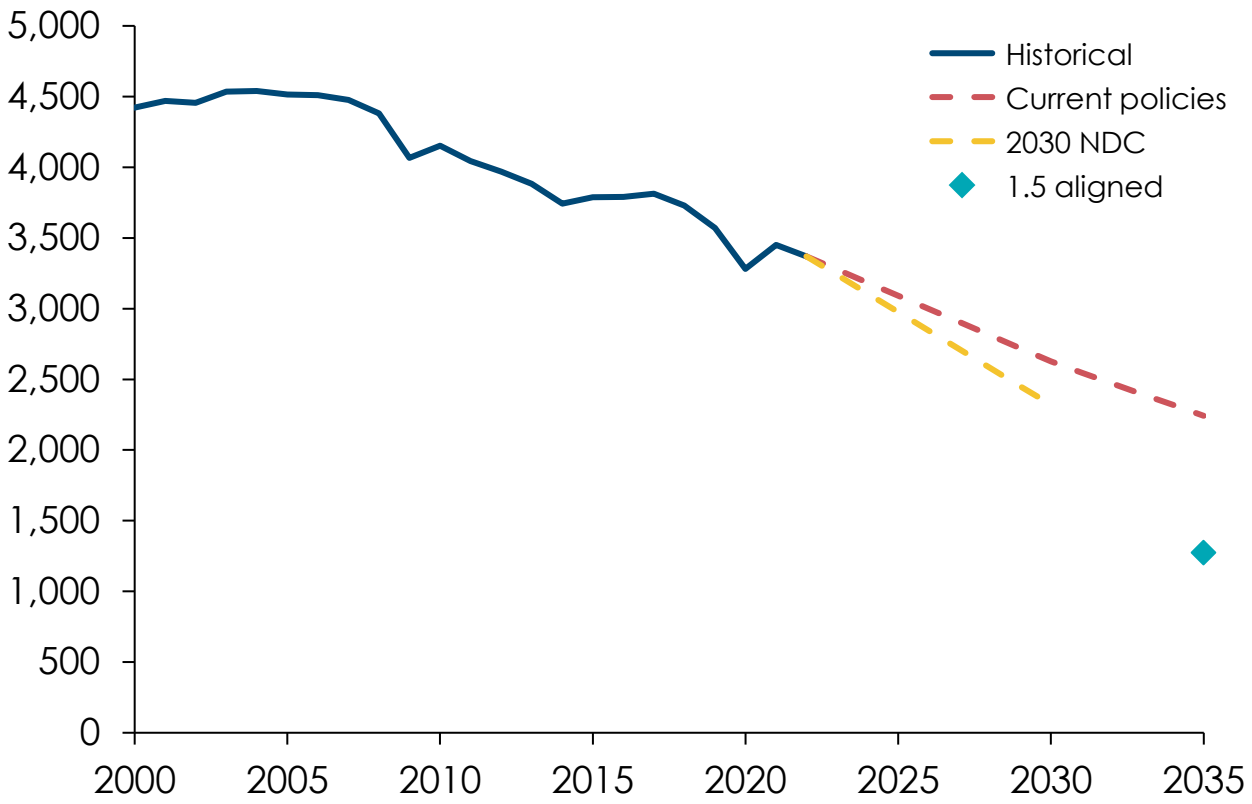
Topic	"Ideal NDC"	Country-level assessments			
		EU	US	China	India
Targets	**Absolute emissions target** (or relative target with necessary information to translate to absolute target), covering **all sectors of the economy and all GHGs**	✓	✓	✗	✗
	Sector-specific absolute reduction targets	✗	✗	✗	✗
	GHG-specific absolute reduction targets	✗	✗	✗	✗
	Quantified contribution of Article 6 mechanisms	✓	✓	✗	✗
	Clear bounds on conditionality	✓	✓	✓	✓
Imple-mentation plans	**Clear implementation plans for sector-level targets**, including **policies, investments and infrastructure buildout**	✗	✗	✗	✗
	Guardrails on inputs and outputs of models used to develop implementation plans	✗	✗	✗	✗

Legend: ✓ *Fully aligned with ideal NDC* ≈ *Partially aligned with ideal NDC* ✗ *Not aligned with ideal NDC*

The EU has an ambition gap of 781 MtCO2e/year, and is a decade behind a fair share 1.5°C scenario

GHG emission reduction scenarios

MtCO2e/year



NDC target overview & areas for improvement

Note: individual member states expected to have these

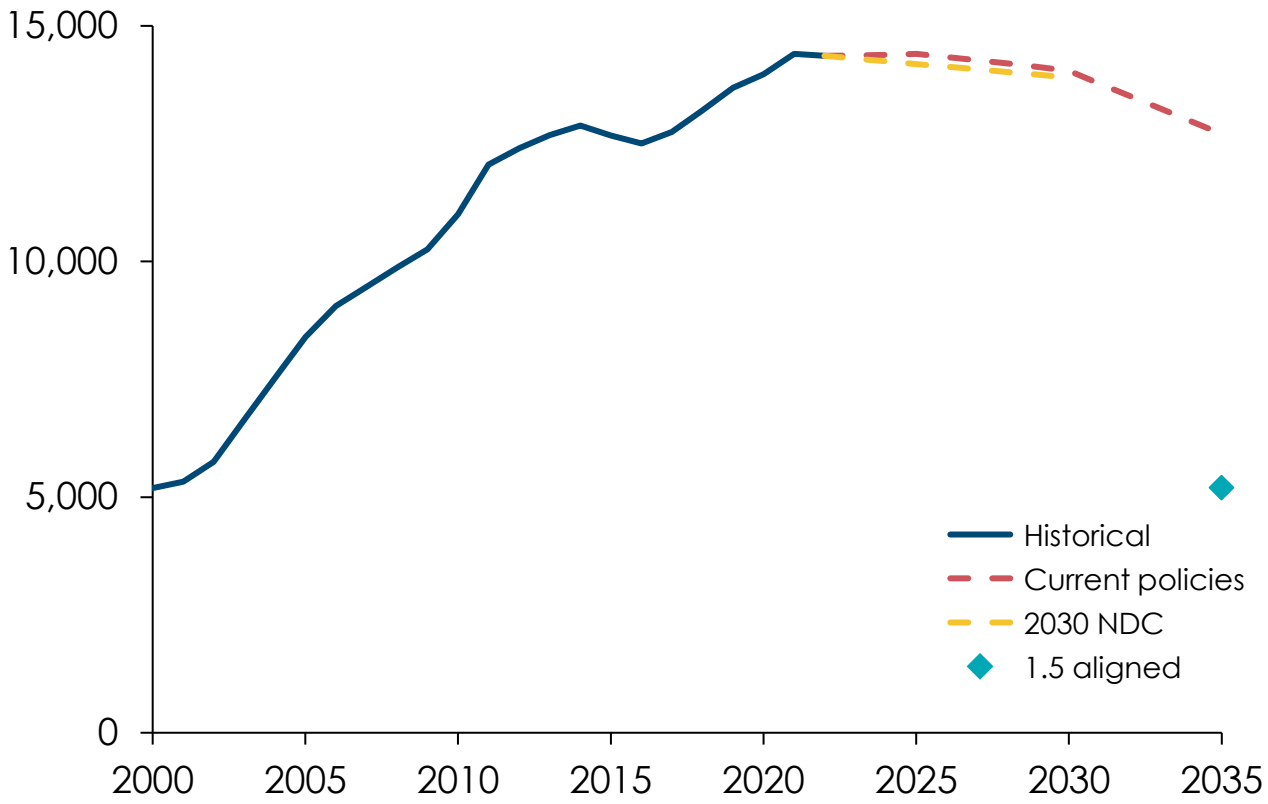
Targets	**Absolute emissions target** (or relative target with necessary information to translate to absolute target), covering **all sectors of the economy and all GHGs**	✓
	Sector-specific absolute reduction targets	✗
	GHG-specific absolute reduction targets	✗
	Quantified contribution of A6 mechanisms	✓
	Clear bounds on conditionality	✓
Plans	**Clear implementation plans for sector-level targets**, including **policies, investments and infrastructure buildout**	✗
	Guardrails on inputs & outputs of models used to develop implementation plans	✗

Source: Climate Action Tracker, Country Assessments, February 2024

While China's Net Zero target is officially 2060, their least cost option pathway is actually less than their fair share, indicating ability to go faster

GHG emission reduction scenarios

MtCO2e/year



NDC target overview & areas for improvement

Targets	**Absolute emissions target** (or relative target with necessary information to translate to absolute target), covering **all sectors of the economy and all GHGs**	✗
	Sector-specific absolute reduction targets	✗
	GHG-specific absolute reduction targets	✗
	Quantified contribution of A6 mechanisms	✗
	Clear bounds on conditionality	✓
Plans	**Clear implementation plans for sector-level targets**, including **policies, investments and infrastructure buildout**	✗
	Guardrails on inputs & outputs of models used to develop implementation plans	✗

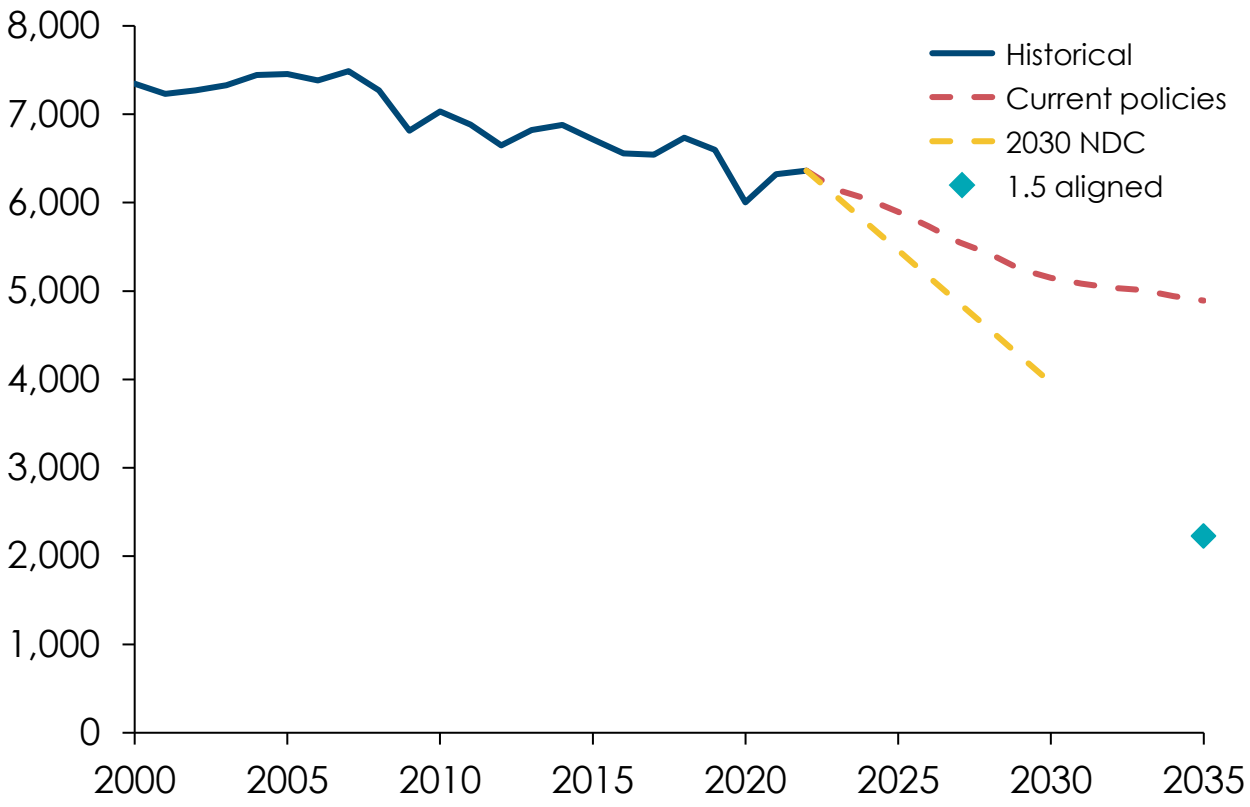
Source: Climate Action Tracker, Country Assessments, February 2024

Legend: ✓ *Fully aligned with ideal NDC* ~ *Partially aligned with ideal NDC* ✗ *Not aligned with ideal NDC*

Unlike China, US NDCs are high ambition but actual pace is behind

GHG emission reduction scenarios

MtCO2e/year



NDC target overview & areas for improvement

Targets	**Absolute emissions target** (or relative target with necessary information to translate to absolute target), covering **all sectors of the economy and all GHGs**	✓
	Sector-specific absolute reduction targets	✗
	GHG-specific absolute reduction targets	✗
	Quantified contribution of A6 mechanisms	✓
	Clear bounds on conditionality	✓
Plans	**Clear implementation plans for sector-level targets**, including **policies, investments and infrastructure buildout**	✗
	Guardrails on inputs & outputs of models used to develop implementation plans	✗

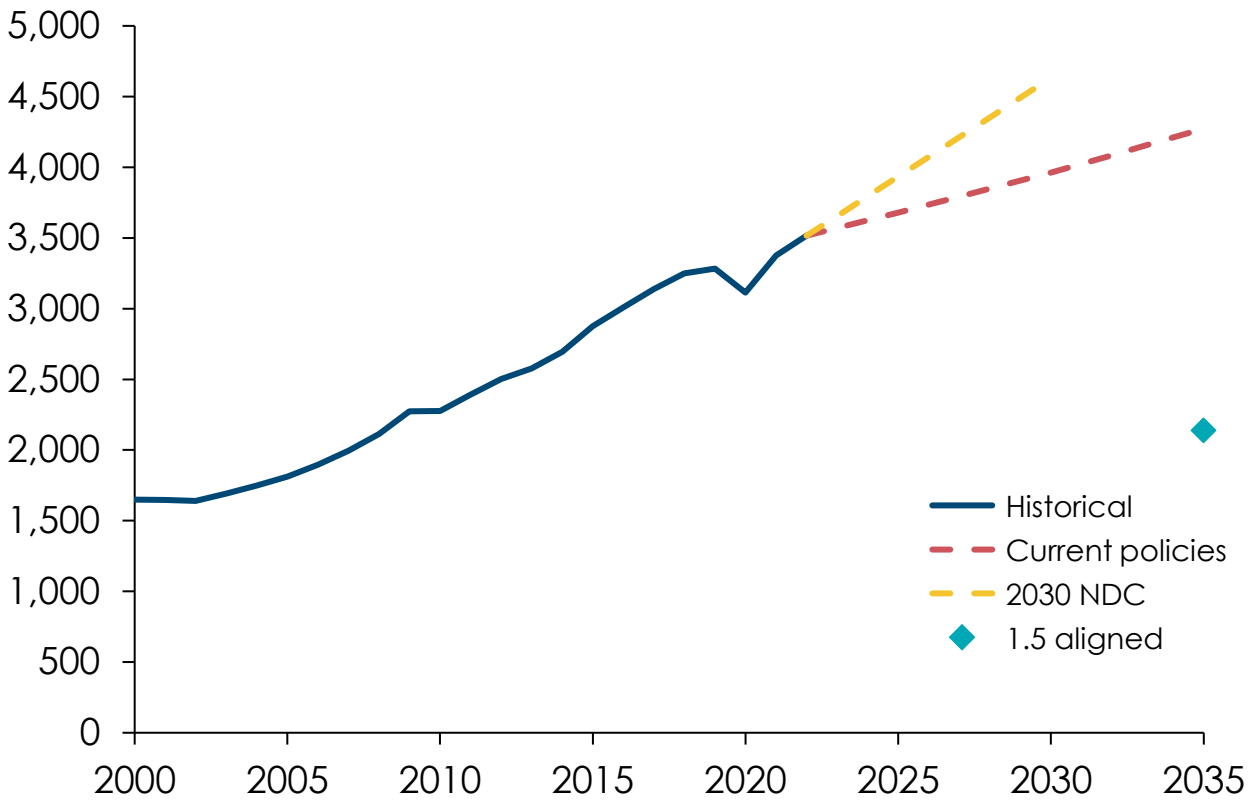
Source: Climate Action Tracker, Country Assessments, February 2024

Legend: ✓ *Fully aligned with ideal NDC* ~ *Partially aligned with ideal NDC* ✗ *Not aligned with ideal NDC*

India NDC is seen to be highly insufficient, but policies and action outperforming the 2030 target

GHG emission reduction scenarios

MtCO2e/year



NDC target overview & areas for improvement

Targets	**Absolute emissions target** (or relative target with necessary information to translate to absolute target), covering **all sectors of the economy and all GHGs**	✗
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	Quantified contribution of A6 mechanisms	✗
	Clear bounds on conditionality	✓
Plans	**Clear implementation plans for sector-level targets**, including **policies, investments and infrastructure buildout**	✗
	Guardrails on inputs & outputs of models used to develop implementation plans	✗

Legend: ✓ *Fully aligned with ideal NDC* ~ *Partially aligned with ideal NDC* ✗ *Not aligned with ideal NDC*

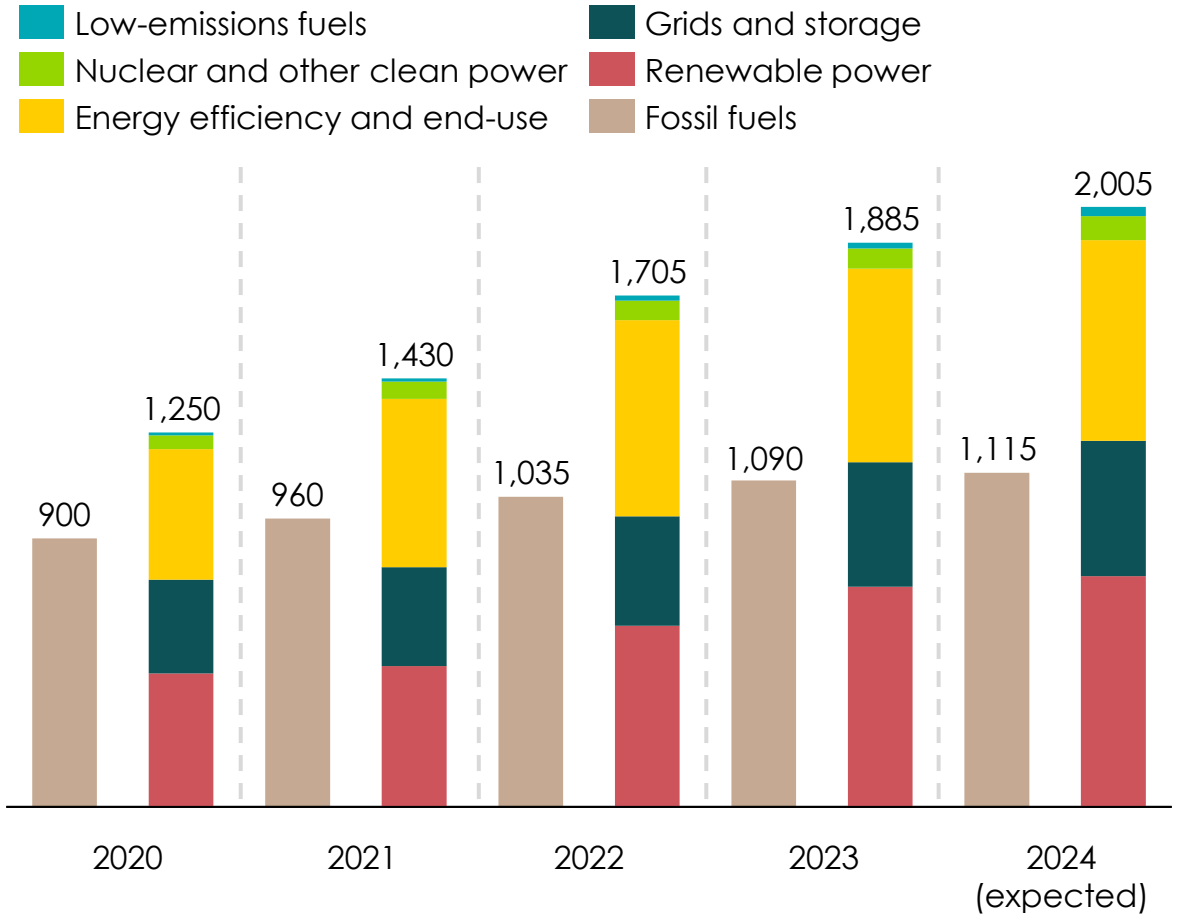
Source: Climate Action Tracker, Country Assessments, February 2024
Note: Unconditional NDC

Part 5. Progress phasing down the fossil system

Led by China and the EU, the world now invests nearly twice as much in clean technologies as it does in fossil fuels

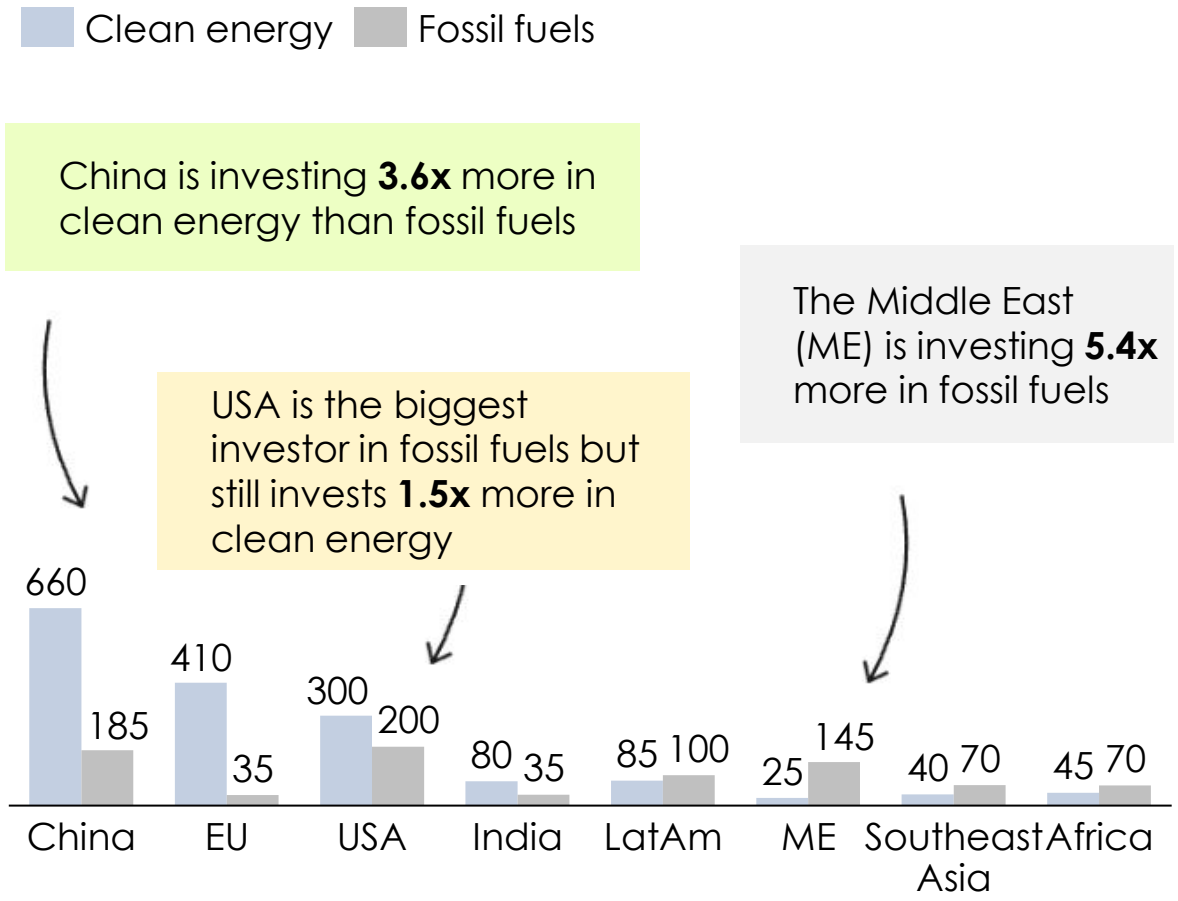
Global investment in clean energy and fossil fuels

Billion USD (2023); 2015–2024



Investment in energy by country or region in 2024

Billion USD (2023)



Source: IEA (2024), *World Energy Investment 2024*

There is an ongoing debate worldwide on phasing down fossil fuel projects

Qatar to increase LNG export capacity in bet on Asian demand

Gulf state's liquefied natural gas production capacity to rise nearly 85% before end of decade

Gas & LNG | LNG | Europe

Europe's gas consumption falls to 10-year low as peak LNG demand nears

Weekly data: US LNG export capacity expected to be 76% higher than EU demand

Analysis from the Institute for Energy Economics and Financial Analysis (IEEFA) raises concern that the US is headed for a liquefied natural gas (LNG) supply glut.

G7 countries commit to closing coal-fired power plants by 2035

The G7 (Canada, the US, France, Germany, Italy, Japan and the UK) collectively announced for the first time a date for the end of coal-fired power generation without CO2 capture and storage.

New coal plants in China soar despite President Xi's pledge to 'strictly control' dirtiest fuel

Big Oil's success in Namibia will push others to drill for growth

Law of averages could catch up with explorers, as typical success rate for a series of offshore wells is around a third

Source: Financial Times; Bloomberg; Energy Monitor; Institute for Energy Economics and Financial Analysis

Risks of fossil fuel infrastructure lock-in continue to arise

Why investment in fossil fuels might be continuing

- **Rising energy demand** in some regions where renewables growth are not keeping pace with demand
- **Geopolitics** making it harder to access cheapest renewable technologies from China
- **Energy security** concerns meaning countries such as the US, continue to invest in LNG assets – partly as a counterpoint to China's growing int'l energy influence
- **"Last man standing" and "fossils as a bridging fuel"** mentality from a number of countries and companies

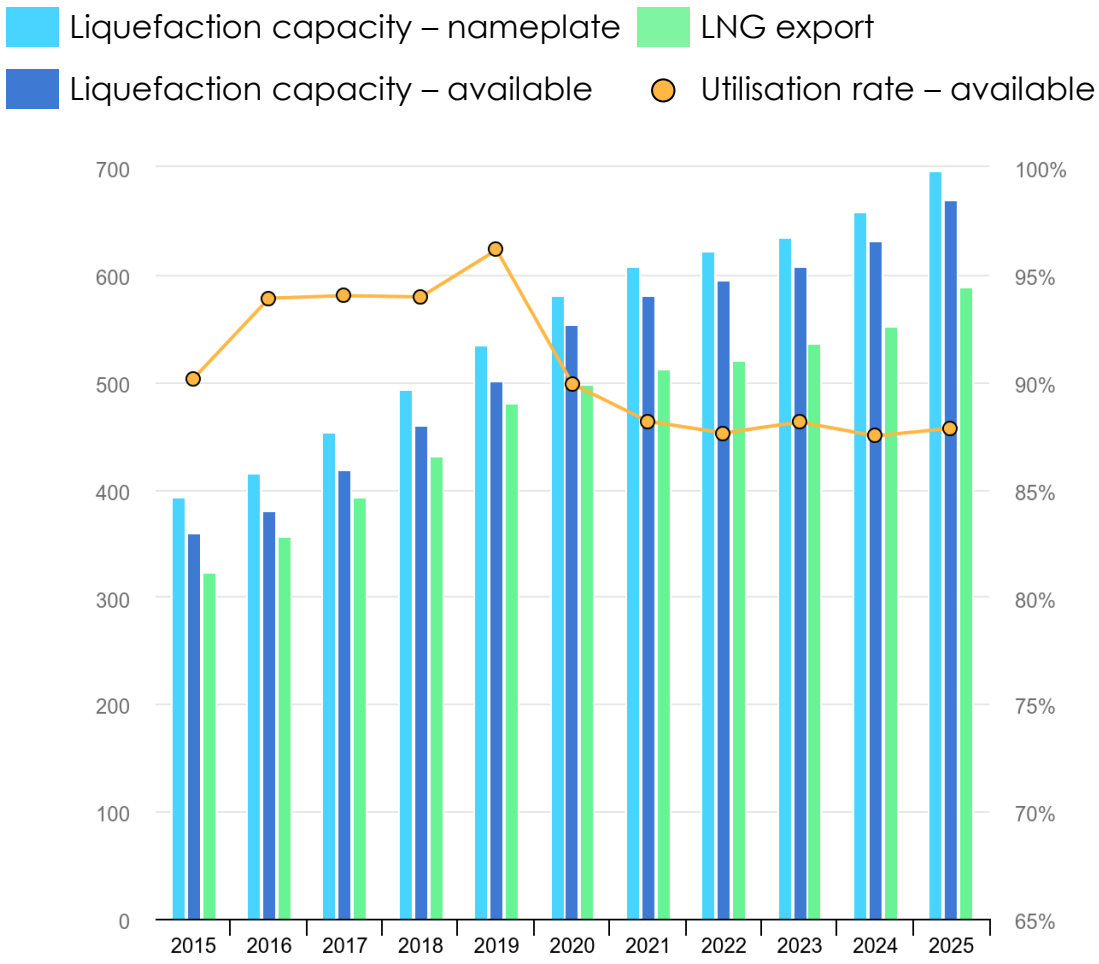
Risks of continued investment

- Risk of investment 'lock-in' for fossil fuel assets, resulting in either:
  - Significant number of stranded fossil assets,
  - Slowing of the transition with maintained reliance of fossil assets, eroding the competitiveness of renewables

Risks of fossil fuel investment lock-in are inherent in the global LNG market, which is facing an overcapacity issue

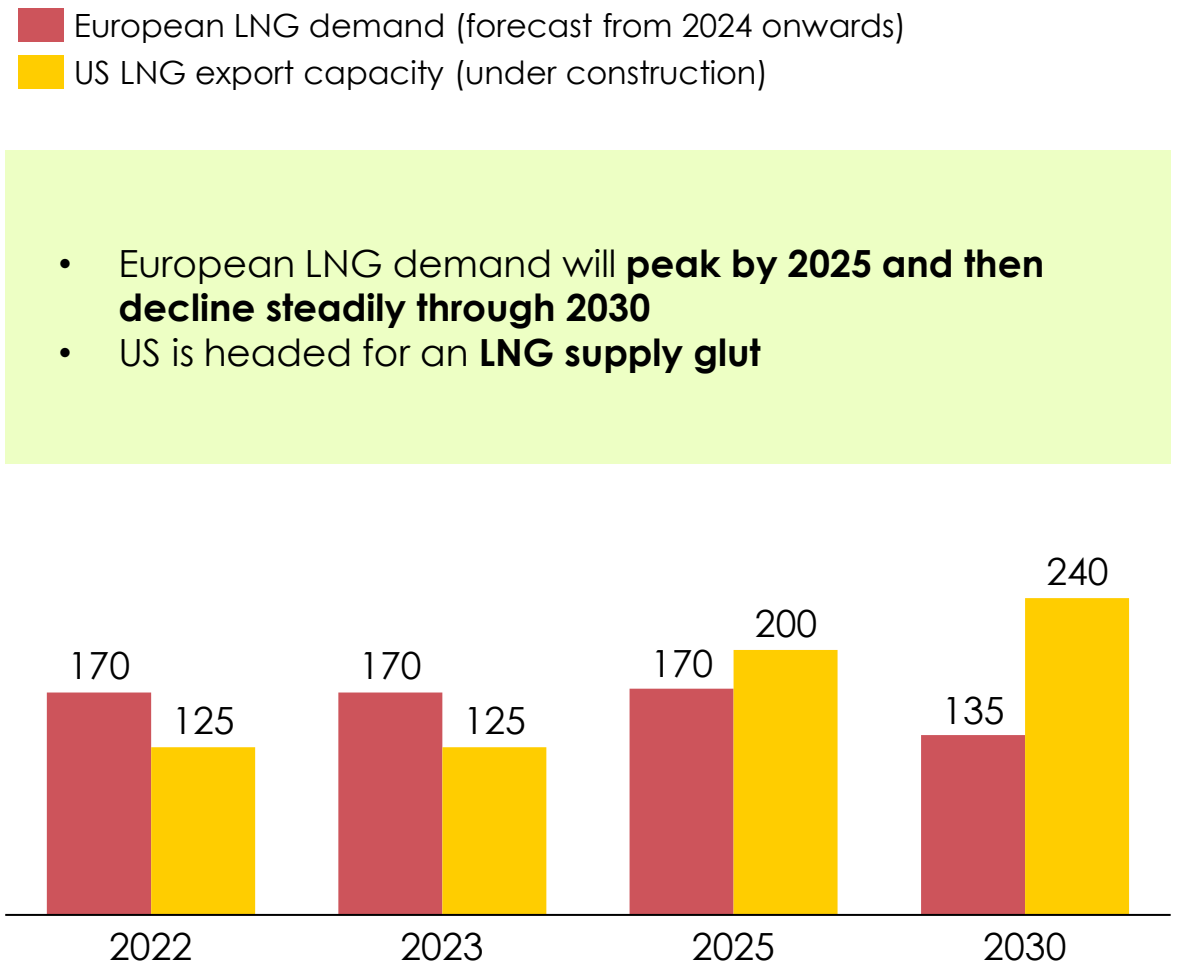
LNG trade and liquefaction utilisation rate

LNG trade and liquefaction -- bcm; utilisation rate – %; 2015-2025



European LNG demand vs.US LNG export capacity

bcm; 2023 – 2030



- European LNG demand will **peak by 2025 and then decline steadily through 2030**
- US is headed for an **LNG supply glut**

Source: IEA (2020), *Gas 2020*; Energy Monitor (2024), *Weekly data: US LNG export capacity expected to be 76% higher than EU demands*

Summary & conclusion for ETC work

Summary and key conclusions

- Emissions still rising but likely beginnings of peak.
- Solar costs continue to come down, albeit at a slower pace than previous years, and capacity is still expected to grow substantially. Innovation driving efficiency improvements and new applications.
- Battery storage system prices also continue to decline, making them more accessible for rapid uptake across multiple uses (storage, vehicles)
- There has been some dampening of the 'hydrogen hype' as electrolyzer costs increase. Key questions remain about whether these costs will come down and whether green hydrogen could have a major role before 2030
- Assessment of progress in key regions highlights increasing policy coverage, but some institutional barriers to progress
- Progress in heavy industry (incl. CCS) and heavy transport remains further behind.
  - Direct electrification technologies are emerging, showing increasing potential against frontrunning solutions to decarbonize heavy industry high-temperature processes.
  - However there is still a need for molecules in materials, chemicals and aviation sectors
- Most regions are now investing significantly more in renewables than in fossil, but for some such as LATAM and Southeast Asia, fossil investment still dominates, despite favourable renewables potential – risks of lock-in.

r future developments, policy priorities… and ETC focus?

trends	Implications and policy / business priorities	Implications for ETC?
falling in energy in China) Policy delivery strengthened but targets insufficient	Essential to accelerate progress by all possible means – moving beyond coal in China and other countries vital Major countries (US, EU and China) should increase ambition and delivery	Further work in China, India and Indonesia? Focus on identifying and communicating - Technology possibility - Barriers and how to overcome them
CDR & Deforestation - Voluntary credits for nature-based removals in crisis Deforestation not reducing	Greater/earlier need for engineered (DAC) solutions - or find ways to make NBS removals work Fundamental consumption drivers- red meat consumption and palm oil – must be addressed	? Vital issue but probably not ETC focus?
Power demand - Even more electricity demand sooner? E.g. EVs, China, electric heat	Massive clean electrification even more important …using all available technologies	Follow through on "Barriers" work vital Assess role of nuclear? – large fission, fusion and SMR?
Hydrogen - Capacity commitments growing, but electrolyser cost reduction slower than hoped and demand growth limited	Policy should drive decarbonisation of existing demand – oil and gas upstream and refining plus ammonia /fertiliser production	Possible deep dive update of ETC 2021-22 analysis ; identify actions to overcome barriers ?

Implications for future developments, policy priorities… and ETC focus?

Latest trends	Implications and policy / business priorities	Implications for ETC?
Solar PV – massiv and continued p	reasingly competitive in sunny d decarbonisation possible in a, Africa	Major initiative in Indonesia? Build on Africa work?
Wind - huge pote approaching tip slower than nee some regions	nakers to focus on detail of upply chain development nd permitting systems	Follow through on "Barriers" work vital
Grid investment vital; local, national and international		
EVs and batteries – massive capacity and approaching up front cost parity	LDVs and 2/3-wheeler sales share to grow faster than previous projections; bigger role also for BEV HGVs Key issue is how fast existing ICE stock turns over in developed and developing countries	Key input to oil demand projections Being addressed in energy productivity work
Heat pumps (and A/C) • efficiency improvement potential • key challenges in installation	Strong policy focus on building heat decarbonisation and cooling efficiency vital • new build design & construction in developing world • existing building retrofit in the developed	Primary focus of energy productivity workstream

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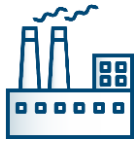
Implications for future developments, policy priorities… and ETC focus?

	Latest trends	Implications and policy / business priorities	Implications for ETC?
	**CCUS** – progres but still behind r	t for early multi company cluster ment of more modular / less	Possible deep dive update of 2021/22 analysis; identify actions to overcome barriers
	**"Hard to abate"** industry sectors; but implementation at early stage	rt needed for first of a kind …plus taxes / regulations / public procurement / voluntary green procurement to overcome "green premium"	Continued focus of MPP work
	Others?		

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Energy
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